JOURNAL OF DAIRY SCIENCE

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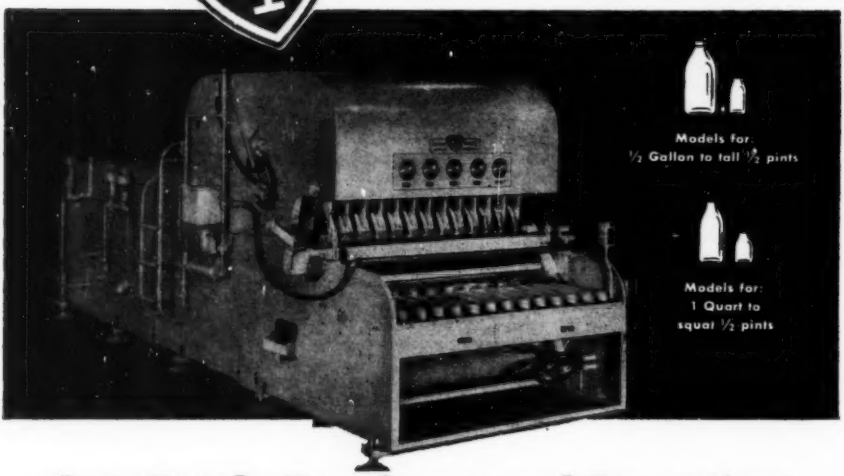

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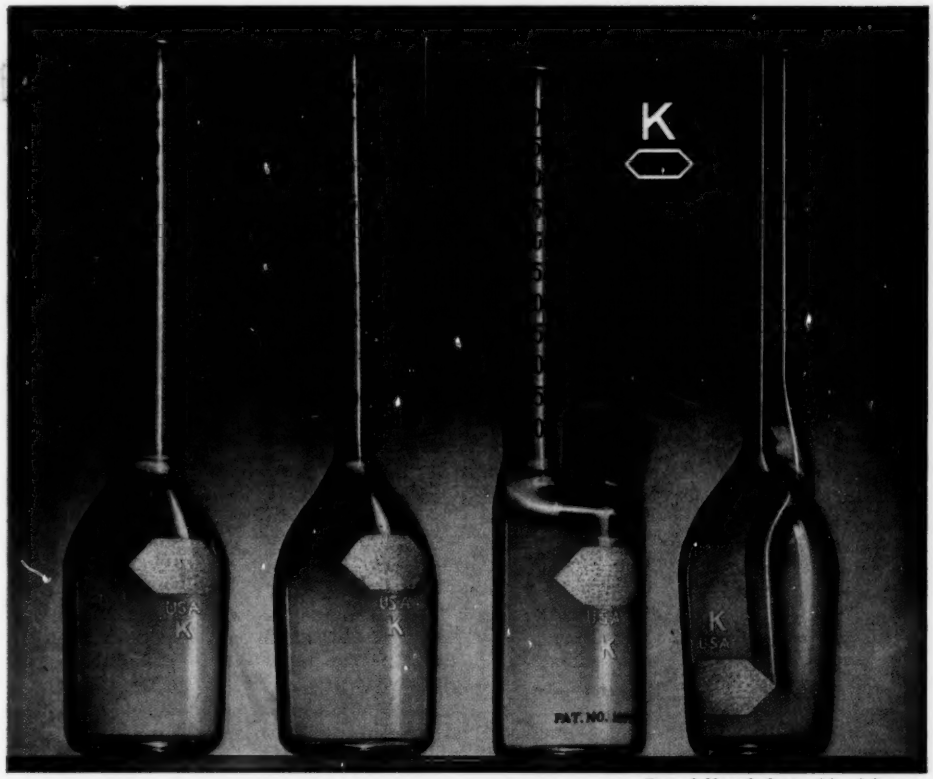

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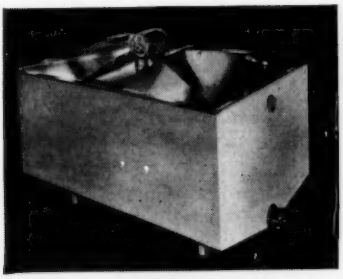

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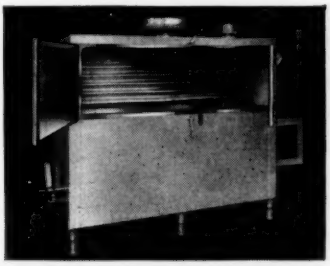

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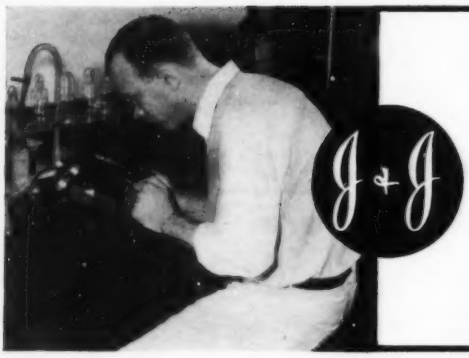

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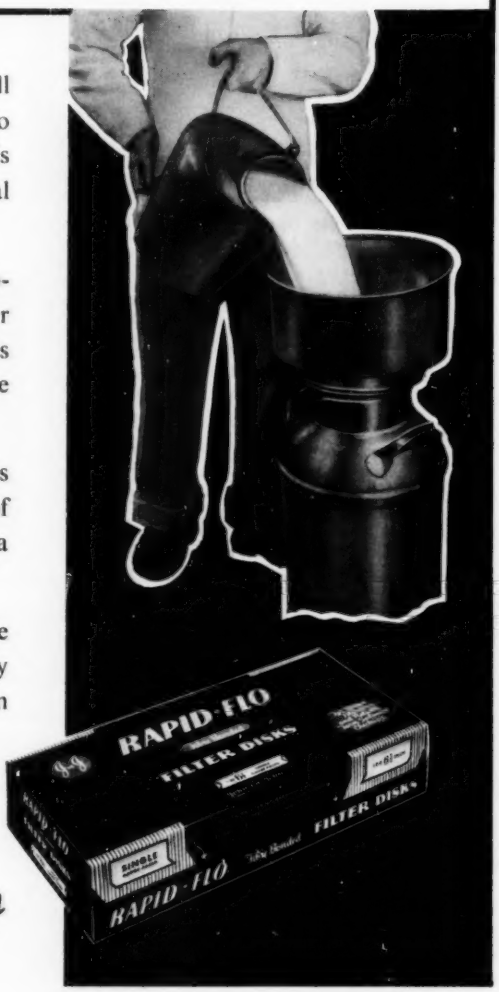

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VOLUME XXXVI December, 1953 NUMBER 12

LEUCOCYTE COUNT OF HERD MILK COMPARED TO THE INCIDENCE OF MASTITIS

PATRICIA MACLEOD, W. N. PLASTRIDGE, E. O. ANDERSON, V. N. GULLET[1], AND H. H. HALE

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Reports in the literature indicate that, in addition to infectious mastitis, the leucocyte count of milk may be influenced by such factors as too vigorous manipulation of the udder (9), incomplete and irregular milking (2, 10), machine milking (5), and the period within the lactation cycle (3, 4, 7). It is generally agreed that milk from healthy cows has on the average fewer cells per milliliter than has milk from infected udders. However, little work has been published regarding the relationship between the cell count of herd milk (as received for processing) and the incidence of mastitis within the herd. In order to study this relationship, the leucocyte counts of the milk from 31 herds were compared with the percentage of animals in these herds that gave evidence of mastitis, as determined by laboratory tests made under the Connecticut mastitis control program. The results of this study, which was started in 1946, are presented in this paper.

METHODS

Leucocyte counts. The milk samples on which the leucocyte counts were made were producer samples delivered to two large processing plants in Connecticut. The samples were collected once a week for 47 weeks. Films were made, stained, and examined according to standard procedures (1). The counts were recorded in millions of leucocytes per milliliter. Sixty microscopic fields on each film were examined, except when the number of leucocytes was large.

Classification of animals within herds. The laboratory examinations of the individual cows were spaced, on the average, 2 to 3 months apart. The milk of each cow was examined by the routine procedures used by the Department of Animal Diseases of the University of Connecticut (6). In this study, the Group II, Group III, and Group V cows within a herd were classified as mastitis animals (8), and the Group I and Group IV animals were considered as healthy.[2]

Received for publication February 5, 1953.

[1] Present address: 55 Branch Brook Drive, Belleville, N. J.

[2] The milk from Group II cows contained more than 1,000,000 leucocytes per milliliter and staphylococci; that from Group III contained more than 1,000,000 leucocytes per milliliter and streptococci other than *S. agalactiae;* that from Group V contained 500,000, or more, leucocytes per milliliter and *S. agalactiae;* that from Group I contained fewer than 1,000,000 leucocytes per milliliter and was free from *S. agalactiae;* and that of Group IV contained less than 500,000 leucocytes per milliliter but yielded *S. agalactiae* on cultural examination.

Statistical analysis. The leucocyte counts of the herd milk samples for the dates just preceding and succeeding that of the state tests were averaged arithmetically, and the average for each herd composed the leucocyte count data used in the statistical computations. The percentages of mastitis animals in each herd at each examination were averaged arithmetically, and these represented the mean percentage infection in each herd over the period of study. A regression curve was calculated by the method of least squares, using the mean percentage of herd infection as the independent variable and the average leucocyte count of milk of each corresponding herd as the dependent variable. The relationship of the average leucocyte count of milk from each herd to the mean percentage of mastitis animals within the herd was investigated by a simple correlation study.

The leucocyte counts of the milk from herds containing from 1 to 20% infected animals (according to state tests) were divided into two groups. The leucocyte counts of the first group were those of milk from herds in which *S. agalactiae* was the sole source of infection (Group V). The leucocyte counts of the second group were those of milk from herds containing animals infected with microorganisms other than *S. agalactiae* (Groups II and III). The cell counts in each of the above mentioned groups were subdivided into those of milk from herds showing from 1 to 9% infection and those of milk from herds showing from 10 to 19% infection.

RESULTS

The mean leucocyte counts of milk from each of the 31 herds are given in Table 1. These are based on the averages of the two leucocyte counts of samples taken before and after the date of the state tests. The period of observation, number of state tests, average number of animals within each herd, and the mean percentage of infected animals within the herd also are shown in Table 1.

The regression curve calculated by the method of least squares, using the data of Table 1 is shown in Figure 1. The mean leucocyte count of herd milk and the percentage of infection within the herd were considered as the dependent and independent variable, respectively. The second degree parabola fitted to the data has the equation $Y = 0.7499 - 0.0338X + 0.0011X^2$, when Y is the mean leucocyte count of herd milk, and X is the mean percentage of infection within the herd.

When the herd infection was at the 15% level, the mean leucocyte count of herd milk was at its minimum point in the curve shown in Figure 1, and from this point on, the leucocyte counts rose steadily. This suggests that if a herd has less than 15% of infection, the leucocyte count of the herd milk may be affected primarily by factors other than the number of mastitis animals within the herd, e.g., the proportion of cows in early or late lactation, whereas above the 15% level, the percentage of herd infection may be the important factor contributing to the magnitude of the count.

If the curve in Figure 1 is continued to the ordinate axis, the average leucocyte count of milk of infection free herds would appear to be approximately 750,000 cells per milliliter. The high cell count (1,000,000 per milliliter) of the

TABLE 1

Percentage of infected animals and the leucocyte count of herd milk (31 herds)

Herd No.	Period of state tests	State tests	Mean cows examined	Mean cows infected	Mean leucocytes cells per ml.
	(Mo.)	*(No.)*	*(No.)*	*(%)*	*(Millions)*
1	9	4	15	8.33	0.15
2	9	4	24	13.40	0.22
3	6	3	26	21.79	0.29
4	9	4	9	5.88	0.36
5	9	4	32	7.75	0.38
6	9	4	11	8.89	0.42
7	9	4	15	13.10	0.42
8	9	4	13	23.08	0.43
9	9	4	22	18.60	0.45
10	9	3	19	23.21	0.49
11	11	5	38	18.56	0 52
12	9	4	26	3.81	0.54
13	10	4	12	8.16	0.54
14	10	4	18	18.57	0.57
15	9	4	10	11.90	0.58
16	10	3	16	16.67	0.59
17	8	3	29	37.50	0.61
18	9	4	13	26.98	0.63
19	9	4	8	31.36	0.68
20	11	4	38	13.70	0.70
21	7	3	8	17.39	0.70
22	9	3	20	15.25	0.70
23	9	4	12	19.15	0.77
24	11	5	34	23.98	0.80
25	5	3	56	24.40	0.84
26	6	3	13	10.53	0.91
27	8	2	14	3.17[a]	0.96
28	9	3	21	52.38	1.75
29	11	5	26	49.62	1.94
30	6	3	19	47.37	1.97
31	9	4	21	49.41	2.01
	Av.	3.7	20.58	20.94	0.739

[a] Five of the 14 cows on the second state test were in advanced lactation (7 to 9 mo.).

milk from herd 27, coupled with the low percentage of infection within this herd, undoubtedly contributed to the aforementioned high cell count for milk from infection-free herds.

If the level of infection within a herd is more than 40%, the mean leucocyte count of the herd milk may be expected to be over 1,000,000 cells per milliliter, as judged from Figure 1. The mean leucocyte count of the milk from 31 herds during the period examined was 740,000 cells per milliliter and the standard deviation of these counts was 490,000. This indicates the very wide variability one may expect to find in the magnitude of the leucocyte counts of herd milk as delivered to processing plants.

The correlation coefficient r was found to be 0.88 and the coefficient of determination 0.78. The latter may be interpreted to mean that 78% of the variation in the mean leucocyte count of herd milk may be explained in terms of the mean percentage of infection within the herd with a 95% confidence interval of 0.94 to 0.77.

The means and standard errors of the leucocyte counts of milk from 25 herds

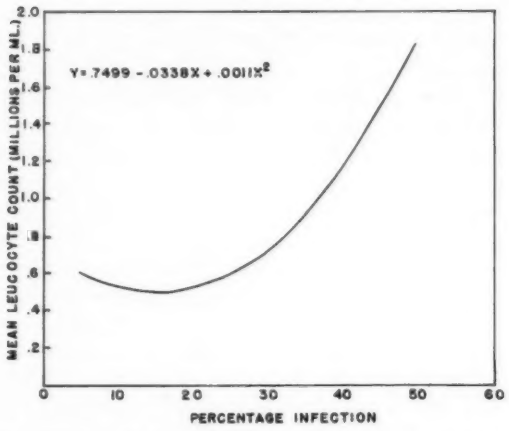

FIG. 1. Regression curve showing relationship of leucocyte counts of herd milk to percentage of infection within a herd.

(showing 1 to 20% herd infection) are given in Table 2. Fifteen of the herds contained Group V but no Group II or Group III animals at the time of testing, and 10 herds showed infections due to organisms other than *S. agalactiae*.

As shown in Table 2, in the herds included in the study, *S. agalactiae* infection was associated with higher leucocyte counts in herd milk than were corresponding percentages of infection with other bacteria. At the 1 to 9% level of herd infection the mean leucocyte count of herd milk was 640,000 per milliliter for *S. agalactiae* infected herds and 420,000 per milliliter for milk from herds infected with other organisms. At the 10 to 19% level of herd infection the mean leucocyte counts of milk from herds infected with *S. agalactiae* or other etiological agents were 710,000 and 470,000 cells per milliliter, respectively. The ratio of these two sets of figures is in the first instance 1.52 and in the second instance 1.51. These figures suggest that on the average the milk from a cow with *S. agalactiae* mastitis will have a higher leucocyte count than one infected with etiological agents other than *S. agalactiae*. It is realized that this suggestion is based on the results of very limited data, and before any conclusive statement can be made on this particular phase of the problem, further study will be necessary. Actually the difference in the cell count means of the two groups at the corresponding levels of infection is not statistically significant, as demon-

TABLE 2

Comparison of the leucocyte counts of milk from herds with S. agalactiae and non-S. agalactiae infections

Mean leucocyte count *(millions per ml.)* of milk from herds with a *S. agalactiae* infection incidence of		Mean leucocyte count *(millions per ml.)* of milk from herds with a non-*S. agalactiae* infection incidence of	
1 to 9%	10 to 19%	1 to 9%	10 to 19%
0.64 ± 0.51	0.71 ± 0.43	0.42 ± 0.37	0.47 ± 0.27

strated by the t values of 1.09 (17DF) for the 1 to 9% group and 0.72 (25DF) for the 10 to 19% group. The fact that the differences are not statistically significant may be because of the limited data analyzed and the great variation in the counts, as shown by the standard errors of the counts in Table 2.

SUMMARY

The leucocyte counts of the milk from 31 herds were compared with the percentage of animals within these herds that gave evidence of mastitis, as determined by laboratory tests.

Statistical analysis of the data collected for this study indicated that 78% of the variation in the average leucocyte counts of herd milk may be explained in terms of the percentage of mastitis animals within the herd. If the percentage of infected animals within a herd, as defined herein, is 40% or more, the average leucocyte count of the herd milk may be expected to be 1,000,000 or more leucocytes per milliliter of milk.

In the herds included in this study *S. agalactiae* infection was associated with higher leucocyte counts in the herd milk than were the corresponding percentages of infection caused by organisms other than *S. agalactiae*. This association, however, was not sufficiently marked to be statistically significant at the 0.05 probability level.

ACKNOWLEDGMENTS

The authors wish to thank C. I. Bliss of the Connecticut Agricultural Experiment Station for his help in the statistical aspects of this paper and the Brock-Hall Dairy Co., Inc., Hamden, Conn., and General Ice Cream Corp., Bryant and Chapman Div., Hartford, Conn., for their cooperation in furnishing the samples of mixed herd milk on which the leucocyte counts were made.

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AN EARLY-GAS DEFECT IN SWISS CHEESE CAUSED BY *BACILLUS POLYMYXA*

R. TJEPKEMA, W. V. PRICE, AND E. M. FOSTER
University of Wisconsin, Madison

A large wheel of Swiss cheese made in this laboratory developed gas during the night on the press table. By 8:00 A.M. the morning after making, the cheese had swelled approximately 3 in. in the hoop. Figure 1 shows the condition of the wheel as it appeared at this time. Thumping of the cheese indicated a general

FIG. 1. The defective wheel of Swiss cheese at 60 days of age.

distribution of this hole formation throughout the cheese. The odor did not suggest the presence of yeasts or coliform organisms. The acidity of the interior of the cheese 24 hours after dipping was pH 5.6, which indicated less acid than normal.

The development of gas in Swiss cheese during pressing is not an unusual occurrence. Several organisms have been identified in the formation of early gas in Swiss cheese.

The coliform organisms have been associated frequently with the production of this early-gas defect (8). Lactose-fermenting yeasts have at various times been involved in early-gas formation in Swiss cheese (4, 7, 12). Galesloot (5) showed that *Betacoccus arabinosaceus* and *B. bovis* may cause early-gas development.

Because the defective wheel made in this laboratory did not seem to have the typical characteristics of cheese affected with early gas, this study was initiated to identify the organism or organisms causing the defect.

Received for publication May 8, 1953.

ISOLATION AND IDENTIFICATION OF THE ORGANISM

Four plugs for bacteriological analysis were drawn aseptically from the cheese within 30 hours of the time it was placed in the brine tank. One plug was taken from the center of each of the four quadrants of the cheese halfway between the circumference and the center of the cheese. The inner 2 in. of each of the 4-in. plugs were placed together in a sterile mortar and triturated with approximately 20 ml. of sterile water.

Dilutions of the triturated sample were prepared to cover the range of 1-1,000 to 1-10,000,000. All dilutions were plated on nutrient milk agar (9) and on tryptone glucose extract agar (9), and duplicate plates were incubated aerobically at 22, 35, and 55° C. The same scheme was followed to produce a second set of plates which were incubated anaerobically in duplicate at these three temperatures using the phosphorus jar technique.

Approximately 90% of the colonies on the tryptone glucose extract agar plates, prepared from the 1-1,000,000 dilution and incubated aerobically at 35° C., were well developed, raised, gummy, and glistening in appearance. Organisms from these colonies proved to be Gram-positive to Gram-variable. They produced gas vigorously in lactose nutrient broth when incubated at 35° C. for 24 hours. Five of the colonies then were selected and plated to achieve pure cultures. The five pure cultures obtained showed the same characteristics as those of the previously tested colonies.

One of the pure cultures then was selected for characterization and identification by the methods described in *The Manual of Methods for the Pure Culture Study of Bacteria* (9). Its characteristics were those listed for *Bacillus polymyxa* in *Bergey's Manual of Determinative Bacteriology* (1).

Since approximately 90% of the colonies on the Petri dish cultures, prepared directly from the cheese, were characteristic of those actually identified as *Bacillus polymyxa*, it was concluded that this lactose-fermenting, gas-forming organism was undoubtedly responsible for the defective cheese. An attempt was then made to reproduce the defect experimentally by using this isolated organism.

REPRODUCTION OF THE EARLY-GAS DEFECT

Selecting the milk. Milk was selected by testing that of various producers for the presence of organisms capable of producing acid and gas in lactose broth at pH 5.0. Lactose nutrient broth with brom cresol purple indicator was prepared, adjusted to pH 5.0, placed in Durham tubes, and sterilized. These tubes of broth were inoculated with 0.1 ml. of the milk to be tested and incubated for 24 hours at 35° C. Tubes which developed neither acid nor gas were presumed to be practically free of *Bacillus polymyxa*.

The milk from the source which had provided practically all of the 2,500 lb. used in making the defective cheese produced acid and gas actively when subjected to the above conditions of incubation in the Durham tubes. Altogether about 60% of the lots of milk examined produced acid or gas or both. Milk from one herd which passed this test satisfactorily was chosen for the attempt to reproduce the gas defect in an experimental lot of cheese.

Making the cheese. Three 50-lb. vats of milk were made into cheese by identical treatments, using the Swiss techniques. All vats received 0.16% *Streptococcus thermophilus* and 0.16% *Lactobacillus bulgaricus* which had been grown in milk for 16 hours. Vats A and B contained milk from the selected source that produced no gas in the Durham tubes under the test conditions. Vat C contained the gas-producing milk from the producer who had furnished most of the milk for the defective cheese. Vat A served as a control. Vat B was inoculated with 10 ml. of a 24-hour broth culture of the organisms isolated from the defective cheese. Vat C was used to see if the defect might be associated with the suspected milk supply.

Each vat of curd was dipped into a single round form and was pressed over night at room temperature (70° F.). The cooling rate was somewhat faster than the normal cooling of a larger wheel, a condition which would not have too serious an effect on the action of *Bacillus polymyxa* but would delay somewhat the development of starter organisms.

Results. No abnormalities appeared in any of the three vats during making or draining or during the early hours of pressing. All three cheeses were examined on the morning after making by slicing them in half. Figure 2 shows the cheese from vats A, B, and C, respectively.

The control cheese from vat A had practically no holes, and those present were apparently of the typical, irregular shape and distribution characteristic of mechanical openings. Cheese from vat B, which contained the inoculation of the isolated organism, *Bacillus polymyxa*, showed the effects of vigorous gas development; it contained numerous gas holes of varying size from those scarcely visible to others approximately ¼-in. in diameter. These gas holes, many of which showed the typical shining interior, were distributed throughout the cheese. The cheese from vat C, which was made from milk from the source largely used in the defective wheel, showed gas holes distributed throughout the cheese. These holes were generally smaller and less numerous than those in the cheese made from the inoculated milk of vat B. Some were irregular in shape like mechanical openings, but many had the typical, round shape and shining interiors of the holes in the defective wheel of cheese.

The organism, *Bacillus polymyxa*, was recovered again from the inoculated-milk cheese of vat B.

PROCESSING OF DEFECTIVE CHEESE

The possible effect of using the defective cheese in making process cheese seemed important enough to investigate.

Method. The original defective wheel of Swiss was given a normal salting treatment and held at a temperature of 50° F. for 10 weeks before comminuting for processing. At that age the cheese was cut in half and photographed, as shown in Figure 3. During the 10 weeks no change in shape or size indicated any further gas development in the cheese.

The processing was done in a small, steam-jacketed kettle with a capacity of

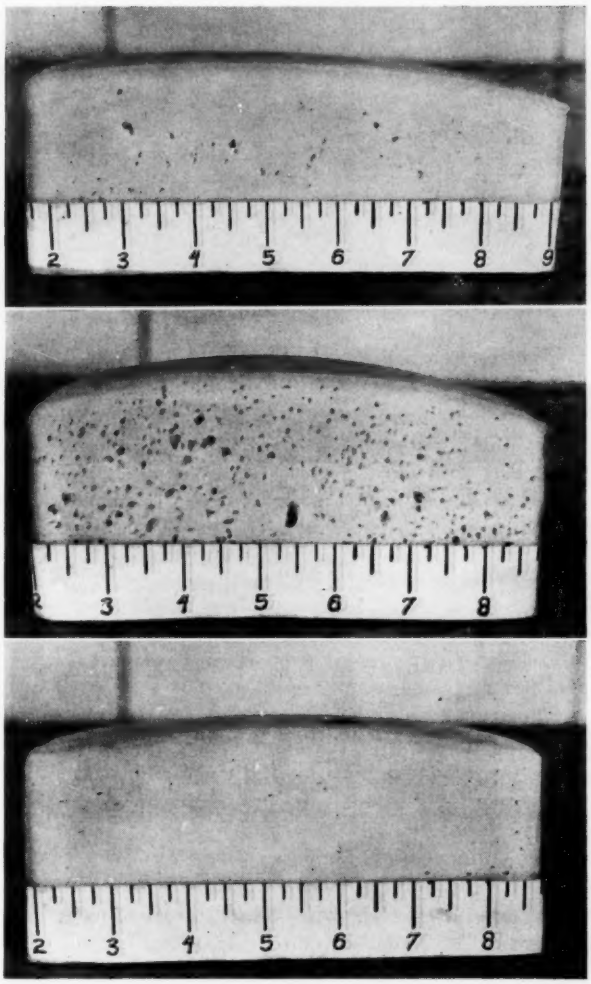

FIG. 2. Cheese at the top is from vat A, center from vat B, and bottom from vat C; vats A, B, and C contained normal milk, milk inoculated with *Bacillus polymyxa*, and milk from a suspected supply, respectively. The scale is inches.

2 lb. Four 2-lb. lots of cheese were made. Each lot was heated to a different temperature, stirred until homogeneous and smooth, and poured into a 2-lb. Parakote pouch and cardboard container. The maximum temperatures used were 150, 160, 170, and 175° F. Holding periods at these temperatures did not exceed 5 minutes. To each batch were added 30 ml. of sterile water and 90 g. of disodium phosphate.

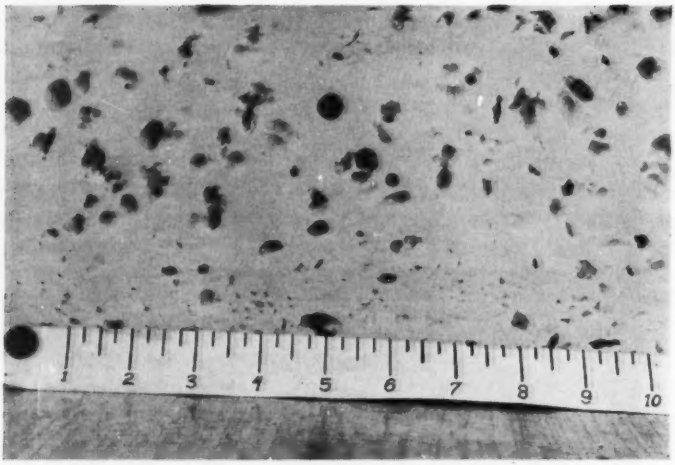

FIG. 3. A cross section of the defective Swiss cheese.

The loaves of process cheese were incubated at 22° C. for 4 weeks and then were held at 35° C. for an additional 2 weeks.

Results. None of the loaves of processed cheese showed any sign of gas production at the end of 4 weeks at 22° C. This result was not unexpected because of the temperatures for growth required by *Bacillus polymyxa.* Within 3 days after exposure to 35° C. the cheese processed at 150° F. showed swelling in the box and an accumulation of gas under the wrapper. Cutting this loaf in half revealed many gas holes. None of the other loaves showed any exterior signs of gas during the incubation periods, and slicing the loaves after incubation showed only a few gas holes in the interiors of loaves of cheese processed at temperatures above 150° F.

After the periods of incubation, *Bacillus polymyxa* could not be isolated from the cheese processed at any of the four temperatures used. It is possible that some heat-resistant, gas-forming organism caused the swelling in the package of cheese processed at 150° F. Other possible explanations suggest themselves, but all are mere speculation, since it was impossible to continue these studies with processed cheese at the time.

DISCUSSION

Bacillus polymyxa is a facultative aerobe which can grow in Swiss cheese before it is cooled and during the salting operation. Davis (3) observed that changes in the oxidation-reduction potential toward the anaerobic condition in the interior of Cheddar cheese occur quickly from the time of manufacture until the end of the first day. Such changes in oxidation-reduction potential would not inhibit growth of *Bacillus polymyxa.*

Conditions for growth of *Bacillus polymyxa* would be particularly favorable

at high pH levels. The pH 5.6 of the defective Swiss wheel at 24 hours after dipping was high for this variety of cheese at that time.

It is possible that *Bacillus polymyxa* is involved in similar defects which have been observed in cheese made in this laboratory and elsewhere in Wisconsin. Such gassy defects have occurred in Cheddar cheese with high pH, and in Brick cheese. The characteristics of the defects in these varieties of cheese, such as time of development, appearance and distribution of holes, lack of objectionable odor, and vigor of development, all strongly suggest the possibility of a common cause.

The feeding of grass silage has been associated with gassy defects in cheese (2). The aerobacillus group of organisms occurs in large numbers in grass silage. These organisms also occur in fairly large numbers in cow and horse feces, sewage, water, and other places (6, 11). Comparison of numbers of these organisms in the rumen contents and the feces of cows has shown a ten to one-hundred-fold increase upon passage through the intestinal tract of the cow (10). Because they require higher temperatures for growth, there is generally little increase in numbers of cells in farm-cooled milk before it is delivered at the dairy plant.

The facts that *Bacillus polymyxa* has been identified in Swiss cheese and that it may be encountered in other varieties of cheese suggest that manufacturers of ripened types of cheese should be alert to this danger.

Practical methods of factory control must vary somewhat with the critical requirements of the type of cheese; they seem at this time to be: *(a)* to use the methylene blue test to screen out milk of inferior quality in order to eliminate the hazard of gross contamination; *(b)* to develop the full limit of acidity or certainly to avoid low-acid development in the making process and in the finished cheese; *(c)* to use the maximum amount of salt; and *(d)* to maintain the cheese at the lowest possible temperatures, especially during the first few hours after making. Laboratory methods of detecting the presence of the specific organisms in the milk supply or on the factory equipment are still not available for factory use.

CONCLUSIONS

An organism causing early-gas defect in Swiss cheese was isolated and characterized as *Bacillus polymyxa*. A pure culture of the isolated organism was used to inoculate a small quantity of selected milk which was made into cheese by the Swiss process; this cheese showed early gas apparently identical to that in the original defective cheese; identical milk made into cheese without such inoculation showed no gas. The organism was recovered from the inoculated cheese.

After 2½ months curing at 50° F., a part of the defective cheese was processed with temperatures of heating ranging from 150 to 175° F. *Bacillus polymyxa* could not be isolated from this processed cheese.

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THE EFFECT OF FEEDING CONCENTRATES WITH DIFFERENT DEGREES OF FINENESS AND WATER CONTENTS ON THE EATING AND MILKING TIMES IN DAIRY CATTLE[1]

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High-producing cows lack sufficient time to consume the necessary amount of grain to meet nutrient requirements in the time usually allowed when milking room procedures are used. Practices which might increase the rate of eating need to be developed. If the physiological and/or physical factors affecting concentrate consumption rates of cattle were known, the problem would be simplied.

The physical nature (fineness of grind) appears to affect concentrate consumption rate. Schalk and Amadon (3), using dairy cows, found the following lengths of time were required for the consumption of 1 lb. portions of the various feeds: whole oats, 2 minutes; corn on the cob, 5.6 minutes; ground grain, 4.7 minutes; and hay, 5 minutes. Harshbarger (1) reported that the time required to consume 1 lb. of different feeds was as follows: ground grain, 2 to 3 minutes; corn silage, 1.75 to 2.75 minutes; and hay, 7 to 16 minutes. Kick *et al.* (2) found that steers fed shelled corn with a modulus of 6.01 and a protein supplement with a modulus of 2.01 required 117 to 185 chews per pound of feed before swallowing. When ground corn with a modulus of 3.56 and a protein supplement with a modulus of 2.01 were fed, 159 to 343 chews per pound of feed were required before swallowing. When shelled corn was fed, prehension was rapid and the corn was swallowed as soon as it was sufficiently covered with saliva to allow easy deglutition.

This present experiment had three objectives: *(a)* to further determine the effect of fine, medium, and coarse grind of grain on concentrate eating time, *(b)* to determine the effect on eating time of adding different amounts of water to the grain, and *(c)* to determine whether either of the above situations affected milking.

EXPERIMENTAL

The cows were housed in a pen-type barn and milked in a U-shaped, four-stall milking room. The animals had free access to hay and either corn or grass silage.

The concentrate mixture was composed of 50 parts shelled corn, 20 parts of oats, 10 parts of rye, 20 parts of soybean oil meal, and 1 part salt. This grain was ground in a Jay Bee Humdinger hammer mill using the following screen sizes: 1/16 in. (fine), 1/8 in. (medium), 5/16 in. (coarse), and solvent extracted soy-

Received for publication May 26, 1953.

[1] Published with the approval of the Director of the Michigan Agricultural Experiment Station as Journal article No. 1510.

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bean oil meal then was mixed with it. The concentrate mixture was measured into the manger by means of a standardized auger with a capacity of 2 lb. of concentrate for each turn. Water then was added. The concentrate and water were mixed by hand immediately if required to make a uniform mixture.

A "Chore Boy" combine milking machine operating at 42 pulsations per minute and with a vacuum of 11 in. of mercury was used during both trials. Preliminary observations showed that let-down of milk occurred about 2 minutes after the cows were stimulated by washing their udders with water at 125 to 132° F. During each trial, with the exception of the final 2 weeks of the second trial when flannel cloths were used, the cows were washed with paper towels. The operator machine stripped by massaging the udders by hand during the last of the milking process.

The cows were fed grain, and the teat cups were put on 2 minutes after udder stimulation. This time was recorded. The time was again recorded when the cow completed eating the concentrate. When a cow did not eat all of the allotted feed, the amount remaining in the manger was weighed and the eating time was calculated on the basis of the amount actually consumed. Since the average pounds of grain consumed and the average eating time per cow were determined, concentrate consumption rate was calculated (minutes per pound). The manner in which the cows ate the grain with different amounts of water also was observed. The average milking time per cow and the average yield of milk per cow were recorded, and the milking rate was calculated (pounds per minute). If a cow did not eat, the data for that milking were not included in the 3-day average.

The first trial extended from January 8 to March 1, 1952. Twelve Brown Swiss cows were used. An air-dry medium grind concentrate was fed for a 12-day period as a control. Each of the three degrees of fineness at each of the water-to-concentrate ratios was fed for a 3-day period. One day elapsed between each 3-day period to permit clearance of residual feed of the fineness of grind previously used. Sixty-two to 72 observations were made for each water-to-concentrate ratio studied.

The second trial was conducted from April 15 to June 3, 1952. Eleven Brown Swiss and two Holstein cows were used. Ten of the Brown Swiss cows used in Trial I also were used in Trial II. The two Holstein cows were removed from the experiment 2 weeks prior to its conclusion because of circumstances beyond control. While the cows were on pasture, the control period of Trial II consisted of 6 days feeding of the coarsely ground concentrate. Fifty-four to 108 observations were made for each water-to-concentrate ratio studied.

RESULTS

Trial I. The time required to consume 1 lb. of grain decreased as the ratio of water-to-concentrate increased (Table 1). When 1.5 lb. of water was added per pound of coarsely ground concentrate, all the water was not absorbed.

The degree of hunger for concentrates of individual cows and even of the whole herd caused great variation in eating times. The degree of hunger appeared

to be markedly affected by the time of day at which the cows ate hay from their self-feeding manger. The cows which were observed to be eating hay just prior to being milked ate their grain much slower than other cows at the same milking. The concentrate eating time was reduced 39% on one occasion when all the cows were confined in the lounging area away from the hay manger to permit cleaning of the exercise lot.

The cows did not pick up the concentrate with their mouths but with their tongues when air-dry concentrates were consumed. The tongue was placed in the feed and the amount that adhered to the tongue was drawn into the mouth.

When 0.5 lb. of water was added per pound of concentrate, the mixture was sticky and tended to form balls. The cows used their tongues to pull the feed into their mouths. They appeared to get more grain in their mouths when the feed was partially moistened and sticky.

The eating time was further decreased when the ratio of water-to-concentrate was increased to 1:1. The cows used a different method of prehension regardless of the fineness of grind. When the concentrate was completely wetted, the cows put their mouths into the feed and swallowed the amount which was enclosed in the mouth each time it was opened and closed. The movement of the jaws, however, was not as rapid as observed in the previous ratios of water to concentrate.

When 1.5 lb. of water was added per pound of feed, the finely ground concentrate was slurry and the coarser concentrates were extremely slurry. The cows drank these concentrates and then used their tongues to clean the mangers. Very little jaw movement was noted until the last of the grain had been consumed.

The faster the cows ate their grain, the faster they milked out. The relationship was not directly proportional but followed the same pattern throughout

TABLE 1

Concentrate consumption rate and milking rate of dairy cows as affected by feeding concentrates with varying degrees of fineness and with varying water-to-concentrate ratios (Trial I)

Fineness of grind	Water-to conc. ratio	Conc. consumption rate		Milking rate		Observations
		Time to consume 1 lb.	Decrease from air-dry[a]	Time to milk 1 lb.	Decrease from air-dry[a]	
	(lb. water/ lb. conc.)	*(min.)*	*(%)*	*(min.)*	*(%)*	*(No.)*
Fine (1/16" screen)	air-dry	1.95	—	0.53	—	66
	0.5	1.69	13	0.47	11	62
	1.0	1.10	44	0.45	15	62
	1.5	0.69	65	0.43	19	72
Medium (1/8" screen)	air-dry	1.90	—	0.54	—	72
	0.5	1.65	13	0.46	15	72
	1.0	1.00	47	0.43	20	72
	1.5	0.91	52	0.41	24	72
Coarse (5/16" screen)	air-dry	1.70	—	0.45	—	70
	0.5	1.24	27	0.45	0	68
	1.0	0.85	50	0.41	9	72
	1.5	0.61	64	0.39	13	72

[a] The air-dry concentrate was used as control for each degree of fineness.

the period of feeding of each fineness of grind and each series of changes of water-to-concentrate ratios. When air-dry coarsely ground concentrates were fed at a ratio of 0.5 lb. of water per pound of grain, the milking rate was not altered much from the control. The largest decrease in eating time and milking time in all instances occurred when 1.5 lb. of water was added per pound of concentrate.

The cows which ate their grain slowly had the slowest milking rates. On one occasion when the whole herd was fastened in the lounging area, the milking rate was decreased by 13% as compared to the previous morning's milking.

Trial II. The results of the second trial are summarized in Table 2. The data show the same general trend as in Trial I in that the concentrate consumption rate decreased when the ratio of water-to-concentrate increased. The milking rate also showed the same general pattern in that as the concentrate consumption rate decreased, the milking rate decreased.

During the latter half of Trial II, when the cows were on pasture, as the ratio of water-to-concentrate increased, the time to consume 1 lb. of feed was decreased markedly. The time to consume air-dry medium and coarsely ground concentrates and the milking rate were much slower than in the control period

TABLE 2

Concentrate consumption rates and milking rates of dairy cows with and without pasture as affected by feeding concentrates with varying degrees of fineness and with varying water-to-concentrate ratios (Trial II)

Fineness of grind	Water-to conc. ratio	Conc. consumption rate		Milking rate		Observations
		Time to consume 1 lb.	Decrease from air-dry[a]	Time to milk 1 lb.	Decrease from air-dry[a]	
	(lb. water/ lb. conc.)	*(min.)*	*(%)*	*(min.)*	*(%)*	*(No.)*
			Barn Feeding			
Fine (1/16" screen)	air-dry	1.61	—	0.43	—	62
	0.5	1.33	17	0.42	2	66
Medium (1/8" screen)	air-dry	1.54	—	0.44	—	66
	0.5	1.22	21	0.36	18	66
	1.0	0.77	50	0.31	30	66
	1.5	0.69	55	0.35	20	66
			Pasture Feeding			
Fine (1/16" screen)	1.0	1.23	24	0.33	25	66
	1.5	1.09	32	0.32	26	66
Medium (1/8" screen)	air-dry	2.41	—	0.42	—	108
	1.5	0.70	71	0.32	29	54
Coarse (5/16" screen)	air-dry	2.51	—	0.41	—	56
	0.5	1.73	31	0.39	5	66
	1.0	1.22	51	0.35	15	66
	1.5	0.77	69	0.26	37	54

[a] The air-dry concentrate was used as control for each degree of fineness.

during barn feeding. When the air-dry medium-grind feed and the water-to-concentrate ratio of 1.5 were used, the milking rate did not show the expected decrease from the control. A relief milker, unfamiliar with the routine, obtained 8.4% less milk than in the previous 3-day period.

DISCUSSION

As shown in Tables 1 and 2, there was a decrease in the concentrate consumption rate as the ratio of water-to-concentrate increased at all degrees of fineness of the concentrate. The higher moisture concentrates appeared to be retained in the mouth for shorter periods of time. This may have been due to the ease of insalivation of high moisture concentrates; Kick *et al.* (2) observed a more rapid deglutition of whole corn grain as compared to ground corn as the result of more difficult insalivation of the ground corn.

The method of eating was changed considerably as the amount of water-to-concentrate was increased. The tongue was placed in the air-dry concentrate and the amount that adhered to the tongue was drawn into the mouth. The cows used their tongues to pull the sticky concentrate into their mouths when 0.5 lb. of water was added per pound of concentrate. Concentrates with a water-to-concentrate ratio of 1:1 were completely wetted, and the cows put their mouths into the feed and swallowed the amount taken into their mouths. The cows drank the slurry concentrates (water-to-concentrate ratio of 1:5) and used their tongues to clean the manger.

Whenever cows failed to eat any feed while they were being milked, milking required much longer on a per pound basis than it did when they ate their feed with relish. The decreased milking rate appeared to be associated with a decreased concentrate consumption rate. This relationship may have been the result of a conditioned reflex and/or an increased feeling of satisfaction associated with the ease of eating (psychosomatic response). As concentrates were fed at the time milking began, this may have contributed further to the let-down of milk. The cows appeared to be more relaxed when they ate concentrates fast.

The results of the second trial when the cows were on pasture agree in general with those of the first trial. Concentrate consumption time was longest on pasture. Probably, because of the quality of the pasture, the cows were not as hungry when they came to the milking room.

SUMMARY

Two trials were conducted to determine the effects of finely, medium, and coarsely ground grain (1/16, 1/8, and 5/16 in. screens) and four different water-to-concentrate ratios (air-dry, 0.5, 1.0, and 1.5 lb. of water per pound of concentrate) on the concentrate consumption rate and milking rate of dairy cows. Twelve Brown Swiss cows were used in Trial I under pen-type barn feeding conditions. Eleven Brown Swiss and two Holstein cows were used in Trial II to study the effects both during barn feeding and when the cows were on pasture.

The data show that as the ratio of water-to-concentrate increased, there was a decrease in eating time. These results have been explained on the basis of changes in the methods of eating concentrates with different water-to-concentrate ratios. There was no significant change in the eating time for the three degrees of fineness. The cows ate air-dry concentrate more slowly when on good pasture than under barn feeding conditions.

As the concentrate consumption rate decreased, there was a corresponding but not directly proportional decrease in milking rate. The proportional change was similar for each water-to-concentrate ratio.

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THE ACTION OF MICROORGANISMS ON FATS. II. SOME CHARACTERISTICS OF THE LIPASE SYSTEM OF *PENICILLIUM ROQUEFORTI*[1]

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A knowledge of the lipase system of *Penicillium roqueforti* is of value in understanding and controlling Blue cheese ripening, since the distinctive flavor of this cheese, for the most part, results from the hydrolysis of cheese fat by this mold (2, 5, 15).

The literature on the characteristics of the lipase system of *P. roqueforti* as influenced by temperature, pH, type of substrate and sodium chloride concentration presents somewhat conflicting and inadequate data. Fodor and Chari (3) reported activities for a mycelial preparation at two temperatures: 30 and 38° C. The rate of lipolysis after 48 hours at these temperatures was variable, depending on the substrate used. Shipe (14) studied the activity of a culture medium preparation at 25, 30, and 40° C. The optimum temperature was found to be between 30 and 35° C. for a reaction time of 2 hours.

According to Thibodeau and Macy (16), the pH optimum of their mycelial preparation was between pH 5.3 and 7.5, and activity was observed over a wide pH range in the presence of acetate buffer when the substrate was a 3% butterfat emulsion. Fodor and Chari (3) claimed that optimum lipolytic activity of the mycelial preparation was at pH 6.5 when the reaction was carried out in phosphate buffer at 38° C. using monobutyrin, methyl butyrate, and olive oil as substrates. However, they presented data on activities at only three pH values: 6.5, 7.0, and 8.0. On the other hand, the culture media from which mycelia were harvested showed lipase activity at pH 8.3, but not at pH 7.0 and 6.5. Shipe (14) concluded that the optimum for the lipase in the culture medium was pH 5.0.

The data of Fodor and Chari (3) indicate possible differences between the mycelial and medium enzyme preparations with respect to substrate specificity. Monobutyrin apparently was hydrolyzed more readily by the mycelial preparation than were olive oil or methyl butyrate. With the culture medium greater hydrolysis was obtained on olive oil and least activity on methyl butyrate.

Shipe (14) determined the relative rates of hydrolysis of tributyrin, tricaprylin, and triolein using an unconcentrated medium preparation at 25° C. in aniline hydrochloride buffer. The greatest activity was observed on tributyrin and the least on triolein. Using a concentrated medium preparation at 30° C., activity was greatest on tributyrin with the activities on tricaproin, tricaprylin, and

Received for publication June 8, 1953.

[1] The data in this paper are from a thesis presented by the senior author in partial fulfillment of the requirements for the degree of Doctor of Philosophy, University of Minnesota. Scientific Journal Series Paper 3008. Minnesota Agricultural Experiment Station.

tripropionin decreasing in that order. Triacetin was not attacked during the 6-hour incubation period.

The data of Thibodeau and Macy (16) obtained with a mycelial preparation on butterfat in acetate buffer initially at pH 6.5 indicate a decrease in lipolytic activity if the reaction mixture contains above 6% sodium chloride. They concluded that sodium chloride, in concentrations such as those existing in Blue cheese (4 to 6%) does not retard the action of the lipase of *P. roqueforti*.

The study reported here was initiated for the purpose of investigating more thoroughly the effects of temperature, pH, type of substrate, and sodium chloride concentration on the activity of the lipase system of *P. roqueforti*.

EXPERIMENTAL MATERIALS AND METHODS

Culture. Minnesota culture P-108-2, a strain regularly used in cheese manufacture, was obtained from the Dairy Bacteriology laboratory, University of Minnesota.

Medium. The media used by others to obtain maximum lipase activity were tried. The medium that produced the best growth was one developed by Thibodeau and Macy (16) —Czapek's solution minus the sucrose and to which was added 3 g. peptone and 3 g. butterfat per liter. The fat was emulsified into the culture medium by means of a hand homogenizer, using 0.5% gum acacia (USP grade) to help stabilize the emulsion. This medium had a reaction of pH 7.0.

Enzyme preparations. The mold was cultured and harvested after the manner of Thibodeau and Macy (16). The mycelial mats were processed in two different ways: *(a)* They were freeze-dried in the apparatus described by Nickerson *et al.* (11), triturated into a powder and held at 1° C. in a desiccator over $CaCl_2$ until ready for use. *(b)* The mats of mycelia were mixed and then frozen. They were held frozen at —29° C. until ready for use, at which time 1 g. of mycelia was homogenized with 9 ml. of distilled water in an Elvehjem-Potter homogenizer (12).

The medium likewise was made into two preparations during the study. *(a)* The filtered medium was freeze-dried, and the resulting powder was held cold and dry in a desiccator over $CaCl_2$. *(b)* The filtered medium was concentrated by fractionally freezing out the water. It was concentrated to a ratio of about 3:1 (4% solids final concentration). These preparations were termed medium preparations.

Generally, 10 mg. of dried mycelia were comparable in lipolytic activity to 0.1 ml. of mycelial homogenate, and 50 mg. of freeze-dried medium were comparable to 1 ml. of medium concentrate. The dried preparations were used for the initial work and for part of the temperature study. The other preparations were used for the remainder of the studies.

Reaction mixtures. The reaction mixtures were: *(a)* 10 mg. or 0.1 ml. of mycelial preparations or 50 mg. of freeze-dried medium preparation and 10 ml. of substrate mixture. The substrate mixture was composed of buffer and 1.0 m*M* of pure substrate or 5% butterfat and at times 0.5% gum acacia. *(b)* A total of

11 ml., which included 1 ml. of medium concentrate and 10 ml. of the above substrate mixture. *(c)* With the electrometric titrations, the amounts of enzyme preparations and substrate preparations given in *a* and *b* above were doubled. Distilled water was used instead of buffer. These preparations were made up fresh for each experiment.

Methods of determining lipase activity. The reaction mixture was titrated with alcoholic KOH after the addition of 50 ml. of a 1:1 solution of ethyl alcohol and ethyl ether and 0.5 ml. alcoholic phenolphthalein (1%) according to the method employed by Thibodeau and Macy (16). Blanks were treated in the same manner and were of the same composition as the reacting mixture except that the enzyme preparation was added after the alcohol and ether at the end of the reaction period. Some blanks were the same as the reaction mixture except that boiled enzyme was substituted for the unheated enzyme preparation. All blanks were incubated the same length of time as the reaction mixture. The mixed indicator of Kleinzeller and Trim (8) was used for values above pH 7.5 in the pH experiments.

An electrometric titration method similar to the one used by Rona and Ammon (13) was also used. The pH was maintained constant in the reaction mixture by the addition of small amounts of $N/10$ or $N/20$ NaOH. The accumulated time and amount of alkali used were recorded periodically. The pH was measured by means of a Beckman glass electrode pH meter, model H2. Blanks were run on the reaction mixture plus boiled enzyme. The formol titration method employed by Fodor and Chari (3) was used in conjunction with the pH study.

For most experiments the reaction time was 1 hour and the temperature was 30° C. The final pH values were determined to check on buffer capacity. In the experiments involving the effect of temperature, the pH was maintained with 0.1 *M* acetate buffer at pH 5.0. Since the pH of Blue cheese is at or near an average of pH 5.0 to 5.5 (1, 10) during curing, acetate buffer at pH 5.2 was selected for substrate specificity experiments and the study of the effect of NaCl on the lipase system.

Enzymatic activity was expressed as the differences in milliliters of $N/10$ or $N/20$ alkali between the titration values of the blanks and those of the reaction mixture. Determinations generally were made in duplicate. Relative activity was expressed as per cent of a common value or as per cent of the maximum value obtained.

Buffers. The buffers used were acetate (6), phosphate (4), and McIlvaine's citrate-phosphate buffer (9). The strength of the buffers was adjusted to minimize any drift of pH during the reaction period.

Substrates. The butterfat used was obtained by churning fresh cream, melting the butter obtained, decanting the oil from the curd, and removing the moisture by heating. In the substrate specificity work the saponification equivalent of about 759 (253×3) was taken as the approximate molecular weight of the butterfat (7).

All of the synthetic substrates, except triolein, were obtained from the Distillation Products Industries, Rochester, New York, and all were U.S.P. grade, except

ethyl caproate, which was technical grade. The triolein (saponification equivalent 293.5) was procured from the Hormel Institute, University of Minnesota, Austin. These substrates were used without being subjected to any further purification. treatment. The insoluble substrates were suspended in the buffer or distilled water by passing through a hand homogenizer four times. This emulsion was stable during the period of the experiment. At times, especially with the more insoluble substrates, 0.5% gum acacia was added to help stabilize the emulsion. The majority of the globules in these emulsions were in the neighborhood of 10 μ with many much smaller.

Experimental conditions were designed so that enzymatic activity was proportional to enzyme concentration in all cases. For example, reaction rates remained constant over a 3.5-hour period. As the amount of enzyme preparation was increased, the amount of acid liberated increased in proportion. It was

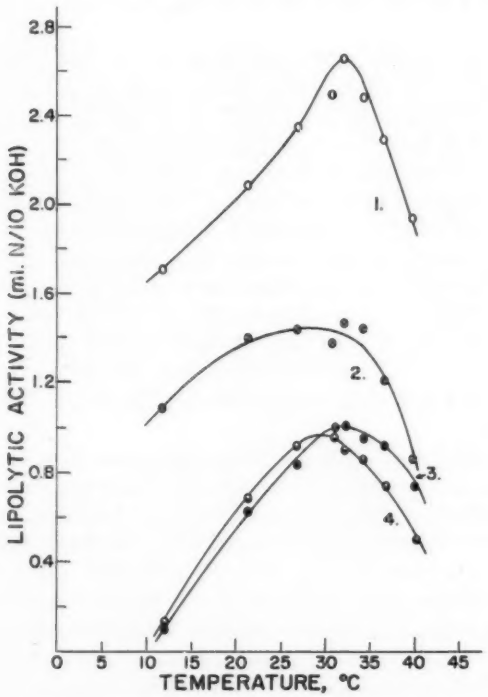

FIG. 1. The effect of temperature on the lipolytic activity of the mycelial homogenate and medium concentrate preparations acting on butterfat and tributyrin substrates.

Time 1 hr. pH—5.0 maintained with 0.1 *M* acetate buffer

1. Mycelial homogenate acting on tributyrin
2. Medium concentrate acting on tributyrin
3. Mycelial homogenate acting on butterfat
4. Medium concentrate acting on butterfat

determined experimentally that the substrates were always in excess for the quantity of enzyme preparations used. Other considerations that were met in order to obtain reliable data were: absence of a preservative in the reaction mixture, minimum effects of bacterial action (short reaction period), and little or no change in pH during the reaction.

RESULTS

The effect of temperature on lipase activity. The data plotted in Figure 1 present the effect of temperature on the lipolytic activity of both enzyme preparations acting on tributyrin and butterfat and indicate that the temperature optimum was about 30 to 32° C. A series of other trials gave similar results. The temperature activity curves are similar for both preparations on butterfat, but not on tributyrin. The reason for the broad temperature optimum range with the medium preparation acting on tributyrin and the reason for the sharply peaked curve obtained with the mycelial homogenate on tributyrin are unexplained. At lower temperatures an increase in temperature increased the rate of hydrolysis markedly. At higher temperatures the rate of temperature inactivation of the enzyme increased and the rate of hydrolysis of the substrate consequently decreased, resulting in a sharp falling off of activity at temperatures

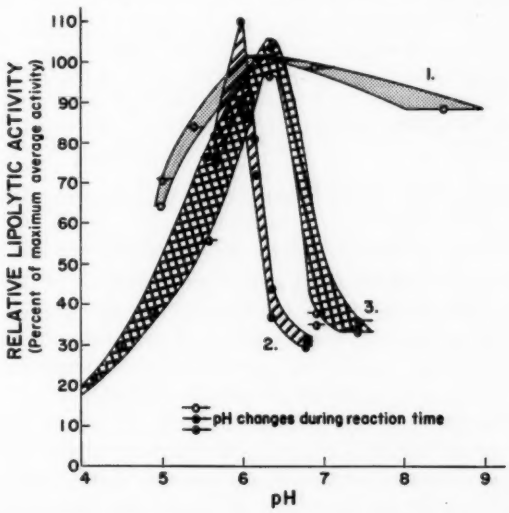

FIG. 2. The effect of pH on the relative lipolytic activity of the mycelial homogenate on tributyrin at 30° C.

1. Titration method—electrometric, time—30 min., substrate preparation—2.0 m*M* tributyrin, 0.5% gum acacia made up to 20 ml. with distilled water.

2. Titration method—Thibodeau and Macy (16), time—1 hr., substrate preparation—1.0 m*M* tributyrin, 0.5% gum acacia made up to 10 ml. with double strength McIlvaine's buffer.

3. Titration method—Thibodeau and Macy (16), time—1 hr., substrate preparation—1.0 m*M* tributyrin made up to 10 ml. with double strength McIlvaine's buffer.

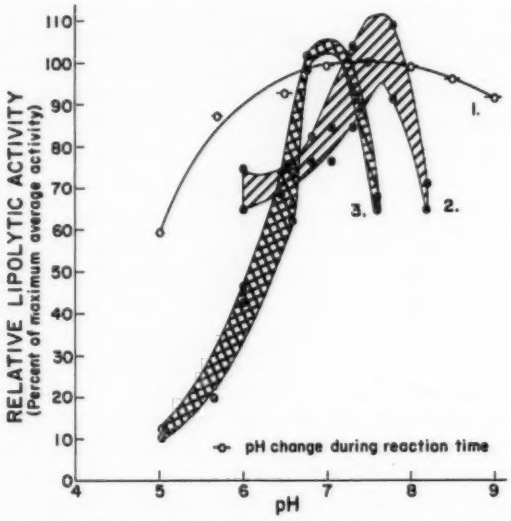

FIG. 3. The effect of pH on the relative lipolytic activity of the medium concentrate (1 ml.) on tributyrin at 30°C.

1. Titration method—electrometric, time—45 min., substrate preparation—2.2 m*M* tributyrin, 0.5% gum acacia made up to 20 ml. with distilled water.

2. Titration method—Fodor and Chari (3), time—1 hr., substrate preparation—1.1 m*M* tributyrin, 0.5% gum acacia made up to 10 ml. with McIlvaine's standard buffer.

3. Titration method—Fodor and Chari (3), time—1 hr., substrate preparation—1.1 m*M* tributyrin made up to 10 ml. with McIlvaine's standard buffer.

above the optimum. It is evident that there would be very little activity above 45° C.

The effect of pH on lipase activity. The effect of variations in pH on the activity of the lipase system is presented in Figures 2, 3 and 4. Instead of representing the pH-activity curves as lines of average values, zones were constructed by drawing lines of best fit showing variations in the data obtained between individual trials or in pH maintained in the reaction vessel, or both, in order to present a clearer picture of the effect of pH.

The pH optimum of the mycelial homogenate acting on tributyrin was pH 6.3 in the absence of buffer as determined electrometrically (Figure 2). With gum acacia the optimum was pH 6.0 and without gum it was 6.25 to 6.45. A broad pH-activity curve was obtained with the electrometric titration method in the absence of buffer. Sharp peaks were obtained in the presence of buffer (Curves 2 and 3 of Figure 2). The differences in the shape of the pH-activity curves in the presence and absence of buffer were due probably to the effect of the buffer on the system. Also, in the presence of buffers a constant ionic strength was maintained which was not the case with the electrometric titration. The constant addition of alkali to maintain the pH relatively constant gradually increased both the ionic strength and the buffering capacity of the system. In

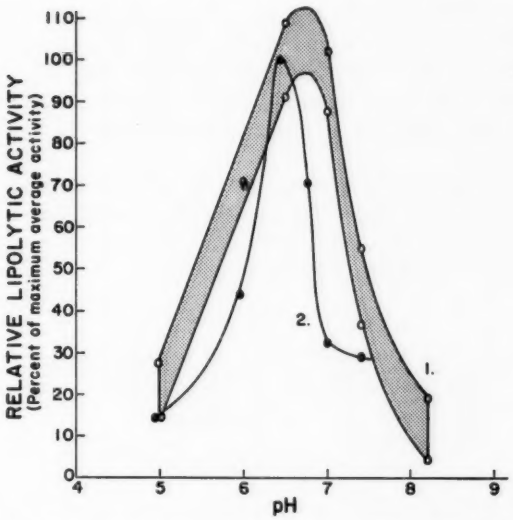

FIG. 4. The effect of pH on the relative lipolytic activity of the medium concentrate on butterfat at 30°C.

Titrations method — Fodor and Chari (3), time — 2 hr.

Substrate preparations:

1. Butterfat (5% of total reaction mixture), 0.5% gum acacia made up to 10 ml., with one-half strength McIlvaine's buffer.
2. Butterfat (5% of total reaction mixture), 0.5% gum acacia made up to 10 ml. with McIlvaine's standard buffer.

addition, in the presence of buffer, pH varied slowly and constantly in a given direction, if at all, whereas in the absence of buffer there were sudden changes and rapid fluctuations within a narrow range.

The phenolphthalein end point was difficult to detect during the titration of the reaction mixture in alcohol and ether because of the insolubility of the phosphate-citrate buffer. Therefore, the formol titration used by Fodor and Chari (3) was employed in the remainder of the studies with this buffer.

When the medium concentrate was tested on tributyrin in the absence of buffer, the pH-activity curve as determined by electrometric titration was broad with the maximum activity at about pH 7.5 (Figure 3). In contrast to this, Curves 2 and 3 obtained in the presence of McIlvaine's buffer have sharp peaks of activity as influenced by pH with the activity diminishing rapidly on both sides of the optimum. With gum acacia as an emulsifier (Curve 2) the pH optimum was about 7.65. Without gum acacia the pH optimum was 7.0.

There seems to be a difference between the two enzyme preparations based on pH optima on tributyrin. When the electrometric titration method was used, the pH optimum for the mycelial preparation was 6.3 and for the medium preparation it was 7.5.

Data representing the lipolytic activity of the medium concentrate on butter-

fat are presented in Figure 4. With a more concentrated buffer and in the absence of gum, the pH-activity curve was characterized by a sharp peak at pH 6.5. With a less concentrated buffer, the pH optimum was about 6.75. The data plotted in Curve 2 are single determinations; therefore, no range is presented. The increased ionic strength of the buffer used may have decreased the pH optimum.

The effect of pH on the lipolytic activity of the mycelial homogenate on butterfat was determined also. The experimental conditions were the same as for Curve 1 of Figure 4. The results were similar. The pH optimum was 7.0 to 7.2 under the conditions of this experiment.

TABLE 1

Comparative activity of mycelial homogenate on tributyrin and ethyl butyrate

Substrate	Reaction mixture	Blank	Av. activity
	(ml. N/10 KOH)		
Tributyrin	4.86	1.61	3.24
	4.82	1.59	
Ethyl butyrate	1.74	1.48	0.22
	1.66	1.47	

Time — 1 hr.
Temp. — 23° C.
pH — 5.2

Substrate preparation:
1.0 m*M* substrate made up to 10 ml.
with 0.1 *M* acetate buffer.

Relative substrate specificity. The mycelial homogenate was tested on tributyrin and ethyl butyrate to determine whether the enzyme system was a lipase or an esterase system. The results are presented in Table 1. The data indicate that a lipase system was involved, since the enzyme system was about 15 times as active on tributyrin as it was on ethyl butyrate. Apparently, it is not a question of the amount of ester linkages present, since, if it were, the activity on tributyrin probably would approximate three times that on ethyl butyrate.

Data representing the activity of the mycelial homogenate on a series of ethyl esters of fatty acids are plotted in Figure 5. There was at least twice the activity on ethyl butyrate as compared to all other esters except ethyl caprylate. It is apparent that as the molecular weight of these esters increased, the rate at which they were attacked decreased, but the decrease was not proportional to the molecular weight. No activity was observed on ethyl acetate. The purity of ethyl caproate was questionable since it was technical grade. This may be the reason for the lower activity of the enzyme preparation on ethyl caproate as compared to ethyl caprylate.

Figure 6 presents the relative activity as a function of the type of triglyceride used as substrate. It is evident that the activity on tributyrin was much greater than any of the other substrates. The activity on monobutyrin was only about 13% of the activity on tributyrin. Butterfat also was used as a substrate in these experiments. The activity on butterfat was about 37% that of the activity on tributyrin. A similar relationship was obtained with the triglycerides as was secured with the ethyl esters. In both cases it may be noted that the activity was lower on esters containing caproic acid than on those containing caprylic acid.

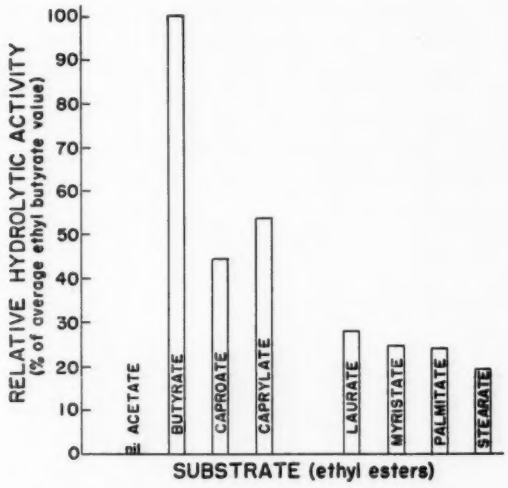

FIG. 5. The relative hydrolytic activity of the mycelial homogenate on ethyl esters of saturated fatty acids.

Time — 1 hr.
Temp. — 30°C.
pH — 5.2

Substrate preparation:
1.0 m*M* of the ester made up to 10 ml. with 0.1 *M* acetate buffer.

The differences between the ethyl caproate and ethyl caprylate (Figure 5) seem to be real, because similar differences were obtained using triglycerides of U.S.P. purity.

The low value for activity on monobutyrin compared to tributyrin possibly may have been due to the differences in the number of ester linkages present. An experiment was set up so that the total number of ester linkages was the same when using tri- and monobutyrin as substrates; that is 1.0 m*M* tributyrin and 3.0 m*M* monobutyrin were used. The activities were 4.2 ml. *N*/10 KOH on tributyrin and 0.84 ml. *N*/10 KOH on monobutyrin. Therefore, increasing the amount of monobutyrin did not proportionately increase the rate of lipolysis. This indicates that the monobutyrin was essentially in excess when 1.0 m*M* was used per 10 ml. of substrate preparation and that the comparative rates were not due to the concentration of ester linkages present.

The relative activity of the concentrated medium on various triglycerides was similar to that of the mycelial homogenate.

The ability of an enzyme to attack a mixture of simple triglycerides or a mixture of mixed triglycerides is of practical importance from the standpoint of cheese ripening. Therefore, the activities of the mycelial homogenate were determined on butterfat and on a mixture of simple triglycerides. The mixture contained approximately proportionate (molar) concentrations of the various fatty acids as butterfat (7). Triolein was the only unsaturated triglyceride used, and there was no tricaprin present. Tricaprylin was used instead of tricaprin

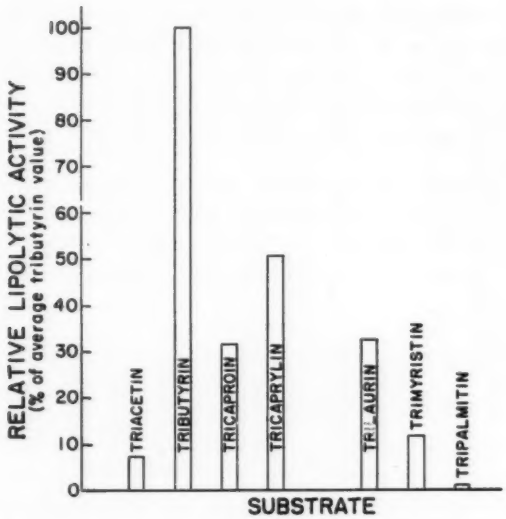

FIG. 6. The relative lipolytic activity of the mycelial homogenate on various triglycerides.
Time — 1 hr.
Temp. — 30°C.
pH — 5.2
Substrate preparation:
1.0 m*M* triglyceride made up to 10 ml. with 0.1 *M* acetate buffer.

on the same molar basis because tricaprin was not available. The physical properties of the "synthetic butterfat" were somewhat similar to those of butterfat. The results of this comparison are presented in Table 2. The lipase system was more active on the triglyceride mixture than it was on butterfat. The presence of the easily hydrolyzed tributyrin in the "synthetic butterfat" may explain the higher activity on the mixture of simple triglycerides. Also, some of the lower molecular weight fatty acids in the mixed triglycerides may be more difficult to hydrolyze than when they occur in a simple triglyceride due to steric hindrance by the longer carbon chain fatty acids.

The effect of sodium chloride concentration on lipase activity. A comparison

TABLE 2

A comparison of the lipolytic activity of mycelial homogenate on butterfat and a mixture of simple triglycerides with a fatty acid composition similar to butterfat

Substrate	Reaction mixture	Blank	Av. activity
	(ml. N/20 KOH)		
Triglyceride mixture	5.47	3.19	2.32
	5.49	3.15	
Butterfat	3.93	2.58	1.39
	4.02	2.59	

Time — 1 hr.
Temp. — 25° C.
pH — 5.4
Substrate preparation:
0.8 g. substrate and 0.5% gum acacia made up to 10 ml. with 0.1 *M* acetate buffer.

of the relative activities of the two enzyme preparations as influenced by sodium chloride concentration is presented in Figure 7. In these experiments an increase in sodium chloride concentration decreased the activity of both enzyme preparations with tributyrin as the substrate. As the salt concentration in the reaction mixture was increased to 4%, there was a rapid drop in lipolytic activity. Afterward, there was a gradual decline in activity as the salt increased to about 16 to 20%. Between 10 and 16% salt concentration, which approximates the

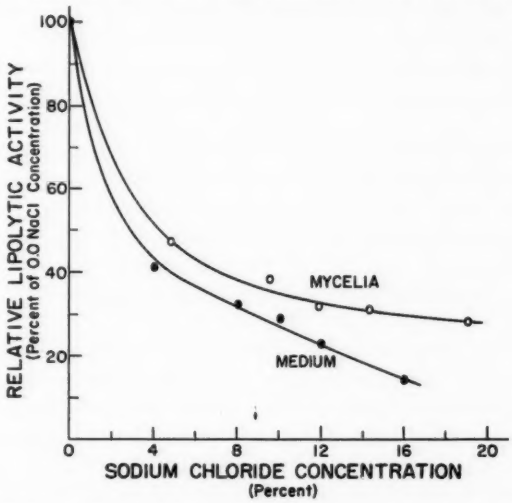

FIG. 7. The relative lipolytic activity of mycelial (0.1 ml.) and medium (1.0 ml.) enzyme preparations on tributyrin as influenced by sodium chloride concentration.

Time — 1 hr.

Temp. — 30°C.

pH — 5.2

Substrate preparations:

Mycelia — 1.0 m*M* tributyrin made up to 10 ml. with 0.1 *M* acetate buffer

Medium — 1.1 m*M* tributyrin made up to 10 ml. with 0.1*M* acetate buffer

concentration in the water of Blue cheese, the activity was below 40% of what it was without any sodium chloride. It would be expected that the amount of salt and its distribution in Blue cheese would be an important consideration in determining the lipolytic activity of the mold.

DISCUSSION

The temperature optimum (30-32° C.) obtained during a 1-hour reaction period in the present work agrees with the data of Shipe (14); however, there is disagreement with the 38° C. optimum obtained by Fodor and Chari (3). Since the latter used a reaction time of 48 hours, one would suppose that the optimum temperature would be lower, rather than higher.

The differences in activities of the medium and mycelial preparations as

influenced by pH and temperature indicate that there may be more than one lipase elaborated by this mold, as suggested by others. Because the pH optima and the temperature-activity curves are somewhat similar with the butterfat substrate and they differ when tributyrin was used as a substrate, it appears that these differences probably are due to a lipase that has greater specificity for tributyrin than for mixed triglycerides.

Nonenzymatic hydrolysis of tributyrin occurred above pH 7.5. It seems possible that as the pH increased, the substrate became more unstable and thus was more easily hydrolyzed by the enzyme system. The influence of gum acacia on pH optima suggests that results obtained on experimental systems containing stabilizers should be interpreted with caution when applying the results to natural systems. The presence of a stabilizer which orients itself at the fat globule surface may possibly interfere with enzyme-substrate contact.

The pH optima vary from 6.0 to 7.8 depending on enzyme preparation, type of substrate, concentration of buffer, and presence or absence of gum acacia. Since Blue cheese has a complicated buffer system, there may be an optimum pH range instead of a single optimum pH for butterfat hydrolysis. From the results obtained on butterfat during this study, this range appears to be near neutrality (pH 6.5 to 7.0).

The pH optima observed in this study do not agree with the data reported by Shipe (14) but are within the range of pH 5.3 to 7.5 determined by Thibodeau and Macy (16). Perhaps the reason that Thibodeau and Macy did not obtain a sharper optimum and the reason that Shipe's data may be questioned is that the capacities of their respective buffer systems probably were exceeded. There is a closer agreement with Fodor and Chari (3), who claimed an optimum of pH 6.5 for their mycelial preparation. With the medium preparation, they reported an optimum of pH 8.3 on monobutyrin, olive oil, and methyl butyrate in phosphate buffer. The deviations of these latter results from the results obtained in this study may be due to the differences in buffers or substrates used or experimental procedures. It was of interest to note that pH 8.3 was the only pH at which they observed measurable activity.

The relative activity of the mycelial preparation on glycerides and on ethyl esters confirmed the findings of Thibodeau and Macy (16) that the lipolytic activity is due to a lipase rather than an esterase system. The results obtained using the medium preparation indicated that there was a decrease in activity as the molecular weight of the fatty acid portion of the triglyceride increased. This finding is in general agreement with that of Shipe (14). This trend also was shown in these experiments with the mycelial preparation acting on both triglycerides and ethyl esters. The low activity values of the enzyme preparations on triacetin and ethyl acetate substrates in an acetate buffer may not be a true picture since the buffer contains an end product of the hydrolysis of these substrates. However, Shipe found no activity on triacetin in the presence of an aniline-hydrochloride buffer using a medium preparation. It may be that acetic acid inhibits the lipase.

The lower activity of the lipase preparation on triglycerides and ethyl esters

containing caproic acid compared to those containing caprylic acid may have been due to a lipase system that has a specificity for esters containing fatty acids of four and eight carbon atoms compared to those of two and six or that the caproic acid was slightly toxic to the system. It may be speculated that the accumulation of caproic acid in Blue cheese is due to the slow hydrolysis of this acid from the glycerides and that the mold may not be able to utilize this acid in its metabolism.

The activity of the lipase system on butterfat falls within the range of activities found with tricaproin, tricaprylin, and trilaurin. Tributyrin was hydrolyzed about eight times as fast as monobutyrin. As time progresses, there is an increasing concentration of di- and monoglycerides occurring in the substrates. This may slow up the reaction in Blue cheese.

The arrangement of the fatty acids in the triglyceride molecule apparently influences lipase activity, because greater activity was observed on "synthetic butterfat," composed of simple triglycerides, than on natural butterfat. The complex mixture of the mixed triglycerides occurring in butterfat makes duplication in the laboratory virtually impossible.

The reduction of activity of both enzyme preparations as salt concentration was increased is generally in agreement with the results obtained by Thibodeau and Macy (16), except that they obtained a slight acceleration of activity at 1, 4, and 6% sodium chloride concentrations. Their data were obtained using butterfat and acetate buffer at pH 6.5. The fact that the buffering capacity of acetate buffer at pH 6.5 is very low may have influenced their results. Thibodeau and Macy showed that at concentrations above 6% there is a decrease in activity. This is in agreement with the results of this study. The conclusion of Thibodeau and Macy that sodium chloride in concentrations such as those existing in Blue cheese does not retard the action of the lipases apparently is in error if the concentration is calculated on a brine basis.

SUMMARY AND CONCLUSIONS

The lipolytic activities of preparations obtained from mycelia of *P. roqueforti* and from the medium on which the mold was cultured have been investigated. The effects of temperature, pH, type of substrate, and sodium chloride concentration on lipolytic activity also have been studied.

The temperature optima of the mycelial and medium preparations on tributyrin and butterfat were between 30 and 32° C. with a reaction time of 1 hour. At low temperatures, an increase in temperatures increased the rate of hydrolysis markedly.

The pH-activity curves as influenced by a variety of experimental conditions have been described. The pH optima obtained were as follows: medium preparation, pH 7.0 to 7.8 on tributyrin and 6.5 to 6.8 on butterfat; mycelial preparation, 6.0 to 6.7 on tributyrin and 7.0 to 7.2 on butterfat.

The lipolytic enzymes present in these two preparations show much greater relative specificity for triglycerides than for ethyl esters. There was consistently a faster rate of hydrolysis by the enzyme system acting on tributyrin than on

any other substrate used. The activity was also greater on ethyl butyrate than on the other ethyl esters studied.

The lipase system was about one-third as active on butterfat as it was on tributyrin. The activity of this lipase system acting on both triglycerides and ethyl esters decreased as the molecular weight of the fatty acid esterified with the alcohol increased. Differences in characteristics of the two enzyme preparations constitute additional confirmation that there may be more than one lipase present in this mold. An increase in sodium chloride concentration decreased the activity of this lipase system.

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AN ACARDIAC MONSTER FROM A COW[1]

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Ottaway (2) has previously reported the birth of an acardiac monster and has reviewed the literature concerning such births. Likewise, Craig (1) and Williams (3) have described these anomalies in some detail. The case recorded is of the type *Amorphus globossus*, sometimes referred to as a "mole" or an anidian monster. Although similar cases have been reported elsewhere, it was thought that a photograph of such a specimen, as well as dissection findings, were worthy of record.

HISTORY AND FINDINGS

A grade Shorthorn cow delivered a normal full-term bull calf. When the placenta was expelled, the monster to be described (Figure 1) was attached. The dam had been bred to a purebred milking Shorthorn bull. It is of some interest to note that the monster described by Ottaway (2) also was born to a grade Shorthorn cow that had been bred to a purebred Shorthorn bull.

The specimen consisted of a hair-covered spherical mass, the greatest length being 3¼ in. and the greatest width 2¾ in. One surface was convex, the other slightly concave with a centrally placed umbilicus with blood vessels. The umbilicus had been severed adjacent to the epidermis and therefore is not apparent in Figure 1.

A sagittal section of the specimen revealed a distinct thick dermal layer beneath the hair-covered epidermis and a central mass of undifferentiated tissue richly interspersed with blood vessels, fat, and connective tissue. Dissection failed to reveal any evidence of bone, reticular areas, internal ridges, or endothelial pouches. The blood vessels did not appear to follow any particular pattern, but there was evidence of circulation. The hair and epidermis appeared to be normal in every way.

DISCUSSION

Craig (1) in his description of "moles" or anidian monsters indicates that they are met with only in ruminants as a rule and especially the bovine species. In nearly every case reported they appear to be one of twins. He further states that they may have skin, bones, teeth, muscles, and even sense organs. Williams (3) indicates that they are attached to the navel cord of the twin, the heart of which sustains the circulation of the monster. Unfortunately, the monster reported here was detached before being observed by the authors, and the exact

Received for publication June 15, 1953.

[1] Contribution from the Department of Dairy Husbandry, Missouri Agricultural Experiment Station, Journal Series No. 1364.

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any other substrate used. The activity was also greater on ethyl butyrate than on the other ethyl esters studied.

The lipase system was about one-third as active on butterfat as it was on tributyrin. The activity of this lipase system acting on both triglycerides and ethyl esters decreased as the molecular weight of the fatty acid esterified with the alcohol increased. Differences in characteristics of the two enzyme preparations constitute additional confirmation that there may be more than one lipase present in this mold. An increase in sodium chloride concentration decreased the activity of this lipase system.

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FIG. 1. Photograph of the acardiac monster showing the size, shape, and the covering of hair.

point of attachment was not determined. Williams also discusses the theories that have been advanced regarding the cause of this type of monster. One theory embraces the idea of fertilization of an imperfect ovum which has developed as a parasite on a normal twin. Ottaway (2) is of the opinion that some factor operates at the time when separation of totipotential cells would ordinarily produce two normal twins but conditions allow the fusion of allantoic vessels, the union of the two individuals by a common placenta, and sustenance of the circulation of the acardiac by means of the heart of the normal twin.

SUMMARY

A report is given of the history and dissection findings concerning an acardiac monster born twin to a bull calf from a grade shorthorn cow. The monster was a spherical mass covered with hair. A sagittal section revealed an undifferentiated mass of tissue containing blood vessels, fat, and connective tissue.

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THE IMPORTANCE OF NUMBERS OF SPERMATOZOA IN RELATION TO SEMEN QUALITY AND FERTILITY OF DAIRY BULLS

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Spermatozoan concentration in ejaculated bovine semen is an important quality test, and it determines the extent to which semen can be diluted for use in artificial insemination (1, 2, 3, 4, 7, 13, 17, 18, 20). Some investigators (5, 6, 8, 10, 11, 12) have recommended that only the semen samples which contain 70% or more motile spermatozoa and 900 $\times$ 10^6 spermatozoa per milliliter of ejaculated semen and which reduce methylene blue in 9 minutes or less be shipped for use in insemination. In all of these studies, however, the dilution of the semen was made on the basis of volume. Branton *et al.* (1, 2) indicated that concentration is an important semen quality test and that bull semen should be diluted on the basis of numbers of progressively motile spermatozoa, rather than by volume. They further recommended that the concentration be at least 500 $\times$ 10^6 spermatozoa per milliliter ejaculated semen. None of these research workers gave much objective data to support their recommended minimum standard for spermatozoan concentration. Some very valuable dairy sires frequently produce semen with spermatozoan concentrations between 500 and 900 $\times$ 10^6 per milliliter. There may be some question as to whether or not such semen can be used with good results.

Investigations by Salisbury (10), Salisbury *et al.* (11, 13), and Willett (18) showed that bull semen could be diluted to 1:100 without any decline in fertility, but dilution levels above 1:100 resulted in decreased fertility. Willett indicated, also, that as spermatozoan numbers were reduced below 6 million, the drop in fertility was more rapid than with numbers above this figure. More recently, however, Willett and Larson (20) found that although there was a very highly significant difference in fertility for semen diluted at 1:100 and 1:300, this difference was no longer significant when the nonreturn averages were adjusted to the same spermatozoan numbers by means of covariance. These results indicate that spermatozoan numbers are much more important than dilution effect in influencing fertility at the dilution levels studied by Willett and Larson. It appears from their data that diluting semen to 8.0-31.2 million spermatozoa per milliliter would give equal fertility results. This is in agreement with the few fertility data available on semen diluted on the basis of numbers of spermatozoa or numbers of motile spermatozoa (2, 3, 4).

In view of the limited amount of data available on minimum standards for spermatozoan concentration in ejaculated semen and on the relation of numbers of motile spermatozoa per milliliter of diluted semen to fertility, the experiments reported here were undertaken.

Received for publication June 25, 1953.

EXPERIMENTAL

The studies consisted of routine semen quantity and quality observations and fertility data obtained in field studies during 1949 and 1950-51 and of a dilution experiment.

Evaluation of semen. The semen quality tests used were the same for the 1949 and 1950-51 data and the dilution experiment. Spermatozoan concentration was determined by use of a Klett-Summerson photoelectric colorimeter which previously had been calibrated by determining colorimetric density readings and hemocytometer counts as described by Salisbury (12) and Willett and Buckner (19).

Initial motility was estimated microscopically. The conventional methylene blue reduction test (6, 8, 12, 13) was conducted for the 1949 data. During the 1950-51 study and the dilution experiment the modified test recommended by Branton *et al.* (1), using 240×10^6 spermatozoa per milliliter or test, was used.

Semen samples which contained at least 50% motile spermatozoa and a minimum of 500×10^6 spermatozoa per milliliter and which had a methylene blue reduction time of not over 9 minutes were diluted and shipped to breeding technicians of the Louisiana Artificial Breeding Cooperative, Inc., for insemination purposes.

Diluters and dilution of semen. During 1949 the semen was diluted with egg yolk-citrate-sulfanilamide at an average rate of $1:74 \pm 4.7$, ranging from 1:27 to 1:140. The citrate buffer used contained 3.0% sodium citrate dihydrate and 0.60% sulfanilamide (5, 13). It was mixed with equal portions of egg yolk to form the diluter. In 1950-51 and during the dilution experiment the egg yolk was mixed with 3.0% sodium citrate dihydrate buffer at a 1:3 ratio (9, 16). The diluted semen contained 300 mg. sulfanilamide per 100 ml. and 500 units each of penicillin and streptomycin per milliliter in 1950-51 and in the dilution experiment. The dilution rate during most of 1950-51 was 12 million motile spermatozoa per milliliter of diluted semen. However, some semen samples were diluted to 10 million. The average for all semen samples, as shown in Table 1, was 11.5 million.

Dilution experiment. Four bulls, two Jerseys, one Holstein-Friesian and one Guernsey, were used in this study. The semen samples were treated by diluting so that portions of each sample contained 12, 6, and 2 million motile spermatozoa per milliliter, as shown in Table 5. The experimental design consisted of 3×3 Latin squares.

Measurement of results. The fertility of the semen was measured by determining the percentages of 60- to 90-day nonreturns to first services. The statistical analyses were carried out according to the methods described by Snedecor (14).

RESULTS AND DISCUSSION

The relationship between spermatozoan concentration in ejaculated semen and fertility in 1949 and 1950-51 is shown in Table 1 on a grouped basis. This

TABLE 1

Relationship between numbers of spermatozoa and fertility

Concentration of sperm/ml.	1949 data				1950-51 data			
	No. of motile sperm/ml. semen shipped	Semen samples	First services	60- to 90-day nonreturns	No. of motile sperm/ml. semen shipped	Semen samples	First services	60- to 90-day nonreturns
(millions)	*(millions)*	*(No.)*	*(No.)*	*(%)*	*(millions)*	*(No.)*	*(No.)*	*(%)*
500- 899	4.2-16.9[a] 7.9[b]	46	1,125	60.4	11.5	36	1,443	69.9
900-1,299	5.4-18.0 10.1	99	2,999	62.8	11.5	117	5,111	68.0
1,300-1,699	6.5-25.7 12.7	86	2,649	65.3	11.5	87	4,086	68.7
1,700-2,099	10.4-33.4 16.6	32	1,211	66.9	11.5	47	2,095	68.2
2,100 and above	16.0-30.4 21.2	12	372	66.4	11.5	10	421	68.9
Total or av.	11.8	275	8,356	64.0	11.5	297	13,156	68.5

[a] Range
[b] Average

table also shows the numbers of semen samples and first services for each group of samples, as well as the average and range in the semen dilution levels used. The same 10 bulls were represented each year. It will be noted that during 1949 fertility increased as concentration increased. In contrast, in 1950-51, when the semen was diluted on the basis of numbers of motile spermatozoa rather than by volume, the fertility levels were uniform in spite of increasing spermatozoan concentration. The 1949 fertility data indicate that approximately equal results were obtained from semen samples which had concentrations of $1,300 \times 10^6$ or more spermatozoa per milliliter when they were diluted to contain not less than 6.5 million spermatozoa per milliliter. On the other hand, good results were secured in 1950-51 with samples which had concentrations as low as 500×10^6 spermatozoa per milliliter when they were diluted to contain constant numbers of motile spermatozoa. It should be mentioned that some of the bulls produced a higher proportion of ejaculates with lower concentrations than others, and vice versa.

TABLE 2

Correlation and regression coefficients between spermatozoan concentration in ejaculated semen and fertility

Data	Statistic	Bases of statistics		
		Total	Among bulls	Within bulls
1949	Correlation	0.164[a]	0.098	0.204[a]
	Regression	0.005	0.003	0.007
1950-51	Correlation	0.042	0.162	0.022
	Regression	0.001	0.002	0.001

[a] Significant at the 1% level of probability.

The total, among, and within bull correlation and regression coefficients between spermatozoan concentration in ejaculated semen and fertility are shown in Table 2. The regressions (b_{yx}) are fertility (y) on concentration (x). The 1949 data clearly show, as was found by other investigators (1, 7, 8, 15, 17), that there is an important relationship between concentration and fertility of semen when it is diluted by volume. In these data there was a highly significant ($P < 0.01$) deviation from linearity. However, when the data were analyzed on the basis of the numbers of motile spermatozoa per milliliter diluted semen the deviation from linearity was not significant ($P > 0.05$). The linear correlations and regressions for 1950-51 (Table 2) were insignificant. Thus, it appears that semen samples with a concentration as low as 500×10^6 spermatozoa per milliliter ejaculated semen can be used with as good results as the more concentrated ones, provided the semen is diluted on the basis of numbers of motile spermatozoa.

As shown in Table 1, the average number of motile spermatozoa per milliliter diluted semen or per insemination was 11.8 million, ranging from 4.2 to 33.4 million in 1949. These numbers of motile spermatozoa were calculated from the dilution ratios, spermatozoan concentration in the ejaculated semen, and the initial motility. The correlation coefficients between numbers of motile spermatozoa per milliliter diluted semen and fertility were 0.219, 0.526, and 0.110 on a total, among bulls, and within bull basis, respectively. The correlation coefficient on a total basis was the only significant one ($P < 0.01$). This was somewhat lower than the 0.491 value reported earlier by Branton *et al.* (1) on fewer samples. Nevertheless, numbers of motile spermatozoa were very important, as is shown by the grouped data in Table 3. In these data, as was no doubt the case with

TABLE 3

Fertility data from semen samples grouped into class intervals of numbers of motile spermatozoa per milliliter of diluted semen in 1949

Motile sperm/ml.	Semen samples	First services	60- to 90-day nonreturns
(millions)	*(No.)*	*(No.)*	*(%)*
4.0- 5.9	16	463	59.8
6.0- 7.9	50	1,557	62.7
8.0- 9.9	51	1,697	62.2
10.0-11.9	44	1,274	62.9
12.0-13.9	36	911	64.1
14.0-15.9	33	1,198	64.2
16.0-33.4	45	1,256	70.5
Total or av.	275	8,356	64.0

those of Willett and Larson (20), the more fertile bulls' semen tended to be more concentrated and to be diluted to contain more motile spermatozoa per milliliter. Consequently, differences among bulls account for most of the upward trend of fertility with increasing numbers of motile spermatozoa per milliliter of diluted semen. That this was true is more clearly shown in Table 4, which presents the total, among bulls, and within bull regression values.

TABLE 4

Regression of fertility on numbers of motile spermatozoa per milliliter diluted semen — 1949 data

X values	$\hat{Y}$ values (% 60- to 90-day nonreturns)		
	Total[a]	Among bulls[b]	Within bulls[c]
(millions motile sperm per ml.)			
4.2	59.8	51.0	62.4
6.0	61.0	54.3	63.0
8.0	62.3	58.0	63.6
10.0	63.6	61.6	64.2
15.0	66.9	70.7	65.8
20.0	70.1	79.8	67.4
25.0	73.4	88.9	68.9
30.0	76.8	98.0	70.5

[a] $\hat{Y} = 0.656X + 57.072$

[b] $\hat{Y} = 1.82X + 43.4$

[c] $\hat{Y} = 0.3137X + 61.1$

A summary of the fertility data (percentages of 60- to 90-day nonreturns to first services) for the dilution experiment is given in Table 5. Statistical analysis of these data revealed that there was no significant difference ($P > 0.05$) between treatments A and B (12 and 6 million motile spermatozoa per milliliter diluted semen). However, treatment C (2 million motile spermatozoa) gave significantly lower fertility than A or B ($P < 0.01$). These results are in agreement with those reported by Willett and Larson (20), whose data showed little differences in fertility from diluted semen containing 10 million or more total spermatozoa per milliliter. Considering the average semen sample to have an initial motility of 60%, this would be 6 million or more motile spermatozoa per milliliter diluted semen. The results reported herein and those obtained by Bratton and Foote (4) also are in agreement. These workers found no difference in the fertility of semen

TABLE 5

Summary of fertility data for dilution experiment

Bulls	Treatments					
	A[a]		B[b]		C[c]	
	Services	N.R.	Services	N.R.	Services	N.R.
	(No.)	*(%)*	*(No.)*	*(%)*	*(No.)*	*(%)*
J105	199	58.3	199	63.8	182	45.6
J109	220	67.3	239	61.5	221	58.8
H211	234	67.9	219	67.6	236	63.1
G304	207	59.9	210	65.2	230	60.0
Total or av.	860	63.6	867	64.5	869	58.2

[a] 12 million motile spermatozoa/ml.
[b] 6 million motile spermatozoa/ml.
[c] 2 million motile spermatozoa/ml.

diluted to 15 and 10 million motile spermatozoa per milliliter, but the portion diluted to 5 million motile spermatozoa gave significantly lower fertility. Therefore, it appears that the minimum number of motile spermatozoa per milliliter diluted semen for optimum fertility results is approximately 6 million. Also, more uniform fertility results usually will be secured among and within bulls when the semen is diluted on the basis of numbers of motile spermatozoa.

SUMMARY AND CONCLUSIONS

Studies were made to determine the relationships between spermatozoan concentration in ejaculated semen and fertility and between numbers of motile spermatozoa and fertility of 10 bulls in 1949 and in 1950-51. Also, a dilution experiment using 2. 6, and 12 million motile spermatozoa per milliliter was conducted. The various correlations and regressions are discussed.

From a review of the literature and the results of the studies reported herein the following conclusions appear to be justified:

1. Semen samples with a spermatozoan concentration as low as 500 million per milliliter will give as good fertility results as more concentrated ones, provided the semen is diluted on the basis of numbers of motile spermatozoa, 6 million motile spermatozoa or more per milliliter.

2. More uniform fertility results among and within bulls can be obtained when the semen is diluted on the basis of a constant number of motile spermatozoa.

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COTTONSEED VS. COTTONSEED MEAL AND CORN AS A PROTEIN SOURCE IN A CONCENTRATE MIXTURE FOR DAIRY COWS

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In an early series of trials, Lloyd (12, 13, 14) compared whole cottonseed with cottonseed meal as a sole concentrate for dairy cows. He found that the cows fed cottonseed produced 75 to 79% as much milk as cows fed cottonseed meal. A few years later, Connell and Clayton (4) reported that three cows full-fed boiled cottonseed plus prairie hay free choice produced slightly more milk than did three cows full-fed cottonseed meal plus similar roughage. In a later trial, in which hay was limited to 10 lb. per head per day, the cows receiving the cottonseed ration produced less milk than those fed cottonseed meal. Moore (24) reported that cows fed 6 lb. of cottonseed produced more milk than cows fed 3 lb. of cottonseed meal. In another trial, cows receiving 3.5 lb. of cottonseed meal produced slightly more milk than others fed 6 lb. of cottonseed. Lush and Gelpi (19) reported that cows fed a ration containing cottonseed meal produced 5.7% more milk than cows fed a similar ration in which whole cottonseed replaced the cottonseed meal. Butterfat percentages varied little in this trial. Davis and Harland (6) replaced 2 lb. of a concentrate mixture with 2 lb. of cottonseed. They obtained no significant difference in the milk yield but did observe an increase in the butterfat percentage during the first 20 days of a 28-day test period.

EXPERIMENTAL PROCEDURES

A double reversal trial of three 28-day test periods with 7-day changeover periods was conducted during the months of December, January, February, and March. Twenty cows which had passed their peak of milk production were arranged in blocks according to age and breed. Individual cows were randomly assigned from these blocks into two groups. Each group contained nine Jerseys and one Guernsey.

The cottonseed ration was composed of equal parts of wheat bran, oats, and whole gin-run fuzzy cottonseed. In the control ration a mixture of four parts of ground corn and three parts of expeller extracted cottonseed meal was substituted for the cottonseed on an equal weight basis. Concentrate allowances were adjusted weekly, each cow being fed 1 lb. of concentrates for each 3 lb. of fat-

Received for publication June 29, 1953.

[1] Data contained in this publication are from a thesis submitted by the senior author to the Graduate School of Mississippi State College in partial fulfillment of the requirement for the degree of Master of Science.

Published as Journal Article 351 of the Mississippi Agricultural Experiment Station.

corrected milk produced per day during the previous week. At the beginning of each changeover period, the groups were abruptly switched from one concentrate mixture to the other. Average quality Johnson or Sudan grass hay and sorghum silage were fed ad libitum, and daily consumption records were kept. Hay was fed in the morning and silage in the afternoon. A mixture of dicalcium phosphate and salt was available in a concrete exercise lot at milking time.

All cows were machine milked in a milking parlor twice daily. Butterfat percentages were determined by the Babcock test on individual samples for four consecutive milkings about the middle of each week. Body weights were recorded as the average of three consecutive daily weights at the beginning and end of each test period. Statistical analysis followed the method presented by Lucas (16) for double reversal trials.

RESULTS AND DISCUSSION

The adjusted means, adjusted mean differences, confidence limits, and coefficient of variation for actual milk production, fat-corrected milk, butterfat percentages, and roughage consumption on the two rations are shown in Table 1. The chemical analyses of the two concentrate mixtures are given in Table 2. The cows gained in weight on both rations, but the difference in gains made on the two rations was not significant. There was no noticeable difference in palata-

TABLE 1

Milk production, butterfat percentage, and roughage consumption per cow per day

	Adjusted means		Adjusted mean differences	Confidence limits		Coefficient of variation
	Cottonseed ration	Control ration		5%	1%	
						(%)
Milk produced *(lb.)*	22.1	21.6	0.46[a]	0.39	[c]	3.1
FCM *(lb.)*	27.7	26.1	1.60[b]	0.40	0.55	2.6
Butterfat percentage	5.70	5.38	0.32[b]	0.11	0.15	3.5
Silage consumption *(lb.)*	32.7	34.2	1.47[a]	1.43	[c]	7.4
Hay consumption *(lb.)*	8.2	8.0	0.23	[c]	[c]	5.0
Hay equivalent consumption *(lb.)*	19.2	19.4	0.17	[c]	[c]	4.7

[a] Significant at 5% probability level
[b] Significant at 1% probability level
[c] Not significant

TABLE 2

Chemical analysis of cottonseed and control rations

	Cottonseed ration	Control ration
	(%)	*(%)*
Crude protein	16.31	16.44
Crude fat	8.44	4.24
Crude fiber	14.71	8.42
Ash	5.67	5.57
Nitrogen-free extract	45.27	55.06
Moisture	9.60	10.27

bility of the rations, although some cows consumed enough of the cottonseed mixture to be receiving 5.5 lb. of raw cottonseed per day.

The cows produced an average of 0.46 lb. (adjusted mean difference) more milk per cow per day on the cottonseed ration. This difference was significant ($P < 0.05$). The difference of 1.6 lb. of fat-corrected milk per cow per day in favor of the cottonseed ration was highly significant ($P < 0.01$). These findings do not agree with the results reported by Lush and Gelpi (19) and Davis and Harland (6) from somewhat similar trials with rations containing cottonseed. However, this increase in milk and fat-corrected milk production on a cottonseed ration containing 8.44% fat over a control ration containing 4.24% fat is in agreement with the numerous reports (8, 15, 18, 20, 21, 22) of increased milk production on 6-8% fat rations which did not contain cottonseed, compared to rations below 3.5% fat. Several trials have been reported in which there was no difference in milk production on rations containing different fat levels, but many of these trials (3, 7, 11, 23, 25, 26) have been on rations much lower in fat and with less difference in fat levels between rations than the 8.44 and 4.24% fat levels in these two rations.

The 0.32% adjusted mean difference in butterfat percentage was highly significant ($P < 0.01$). This is in agreement with earlier reports of increases in butterfat percentages on rations containing cottonseed (5, 6, 14, 24). However, Lush and Gelpi (19) reported that butterfat percentages varied little in a somewhat similar trial with a ration containing cottonseed. The increase in butterfat percentage agrees with numerous results from feeding high fat rations which did not contain cottonseed (1, 2, 3, 10, 17, 21, 27, 28). It has been suggested that this increase in fat percentage is of a temporary nature (9, 10). Davis and Harland (6) reported that the increase in butterfat percentage on a cottonseed ration continued for the first 20 days of their 28-day test period.

In this trial when the butterfat percentages were compared by weeks within periods, they were consistently higher when the cows were on cottonseed than during the corresponding week on the control ration. Statistical analysis of the data by weeks showed this difference to be highly significant ($P < 0.01$) for each of the 4 weeks within the test period and for the changeover week. This indicated a relatively quick increase in fat percentages, since it was only 48-72 hours from the change to the cottonseed ration until the first milk samples were taken. Although the difference was largest in the first week of the test period, it was still large enough to be highly significant in the 4th week of the test period, or 5 weeks after going on the high fat cottonseed ration.

The average roughage consumption for all the cows on both rations was 2.17 lb. of hay equivalent per 100 lb. of body weight. The cows consumed significantly ($P < 0.05$) more silage when on the control ration than on the cottonseed ration. They consumed slightly more hay on the cottonseed ration. This difference in hay consumption approached significance at the 5% probability level. When the hay and silage consumptions were combined as hay equivalent, the difference in consumption was not significant.

SUMMARY

Cottonseed and cottonseed meal were compared as protein sources in a 17% protein mixture in a double reversal feeding trial. Differences in production of fat-corrected milk and butterfat percentages in favor of the cottonseed ration were highly significant ($P < 0.01$). Milk production was significantly higher ($P < 0.05$) on the cottonseed ration. Differences in roughage consumption and gains in body weight were not significant.

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THE RESPONSE OF HORMONALLY INDUCED BOVINE MAMMARY TISSUE TO ANTERIOR PITUITARY HORMONES

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In previous work from this laboratory (4) the mammary tissue obtained as a result of treating dairy heifers with a combination of stilbestrol and progesterone was observed to be more normal histologically than that obtained as a result of administering stilbestrol alone. This finding is in agreement with work recently reported by Cowie *et al.* (2), in which similar hormone treatments were given ovariectomized goats.

Since in this earlier study the heifers were sacrificed before any appreciable milk production was obtained, it seemed desirable to investigate further these distinct types of mamary tissues by collecting lactation data on a similar series. In the present work, mammary growth was stimulated by either stilbestrol alone or stilbestrol plus progesterone. Following this treatment, lactation was encouraged by the administration of various anterior pituitary preparations. In doing this an attempt was made to determine which of the two types of tissue was more responsive to pituitary hormones. In addition, the relative lactation effects of some anterior pituitary preparations were tested.

PROCEDURE

Two groups of six Holstein heifers were treated as follows: Group 1 was injected with 2 mg. of stilbestrol in olive oil subcutaneously three times weekly from 6 to 11 months of age; Group 2 received stilbestrol in the same dosage as Group 1 and in addition was injected with 80 mg. of progesterone in oil three times weekly from 7 to 11 months of age. During the course of these injections the heifers were milked whenever their udders appeared to be unduly distended, and in every case regular milking was instituted at the age of 11 months, at which time the stilbestrol and progesterone were withdrawn.

Two weeks after the last injection of estrogen or estrogen and progesterone the administration of pituitary hormones[1] was begun. The pituitary preparations were administered according to one of the following sequences: *(a)* prolactin → growth → crude extract, *(b)* growth → growth + prolactin → crude extract, or *(c)* thyrotropin → growth → crude extract. These hormones were in aqueous medium and injected intramuscularly over a period of about 6 weeks. The hormone dosage and intervals of injection are given in the accompanying lactation curves (Figures 1, 2, and 3).

Received for publication July 8, 1953.

[1] The prolactin used in these studies was supplied through the courtesy of Dr. R. W. Bates, E. R. Squibb & Sons, New Brunswick, N. J. The other pituitary hormone preparations were supplied by Dr. Irby Bunding, Armour Laboratories, Chicago, Ill.

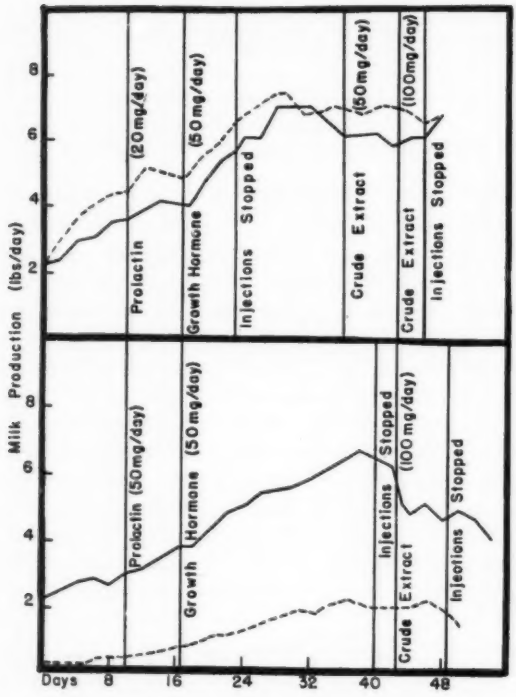

FIG. 1. Milk production of heifers injected with prolactin and growth hormone preparations.

The pituitary growth hormone preparations which we have used contained from 51 ± 17% to 141 ± 36% of the growth activity of the 22 KR_2 Armour standard. The major pituitary hormone contaminant of these preparations was thyrotropin. T.S.H. activity of the growth hormone preparations was approximately 0.08 U.S.P.-T.S.H. units per milligram.

Two thyrotropin preparations were used. One of these contained 0.2 U.S.P.-T.S.H. units per milligram and the other 0.5 U.S.P.-T.S.H. units per milligram. Dosage was adjusted to account for these differences in potency in the experiments in which these preparations were used. These thyrotropin preparations also contained small amounts of growth hormone, prolactin, gonadotropin, and ACTH.

The crude extract used was a less highly purified growth hormone preparation with about 25% of the activity of the 22 KR_2 Armour standard. It also contained some prolactin, T.S.H., and ACTH, presumably in larger amounts than in the more highly purified preparations.

The heifers were slaughtered at 13 months of age, and the udders were fixed in Bouin's solution. Representative samples of the mammary glands were prepared for histological examination.

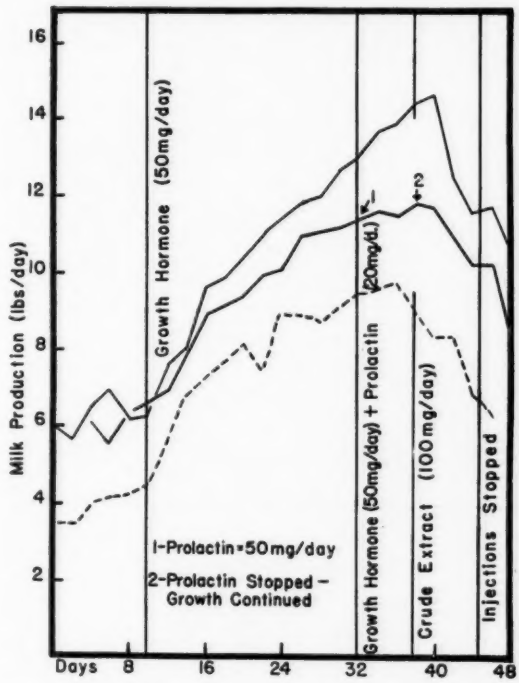

FIG. 2. Milk production of heifers injected with growth hormone and growth hormone plus prolactin.

RESULTS AND DISCUSSION

Figure 1 shows milk production curves of the four heifers which received the prolactin → growth → crude extract sequence. The heifers which were initially primed with a combination of stilbestrol plus progesterone are represented on the production graphs as interrupted lines; those which received only stilbestrol are shown by the solid lines. The milk production was not materially affected by administration of prolactin early in lactation. The response to growth hormone, however, was rather marked, and increases attributable to this preparation were obtained in each of these heifers. The crude extract was without noticeable effect.

The results of the growth → growth + prolactin → crude extract sequence are shown in Figure 2. One heifer orginally scheduled for this group is omitted from the graph. During her lactation this heifer produced from only one quarter, and it was discovered at autopsy that the other quarters were blind. No teat cisterns were present in these affected quarters. This group of heifers responded markedly to administration of growth hormone. When these animals were given prolactin in addition to the growth hormone preparation, there was only a very slight additive stimulus to increased production. In the heifer in which prolactin

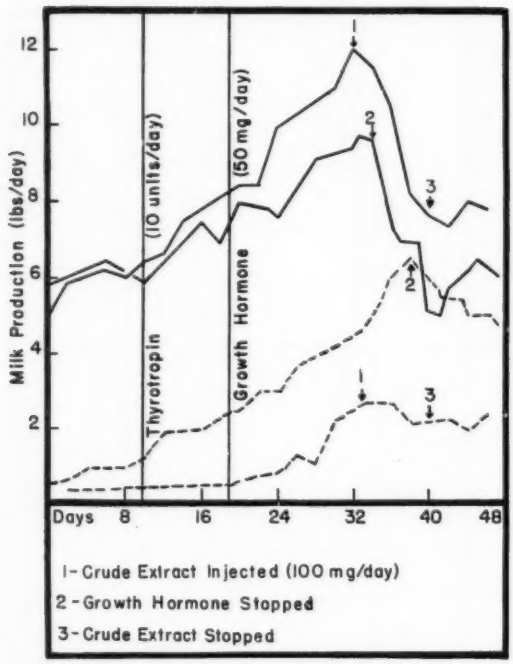

FIG. 3. The effect of thyrotropic and growth hormone preparations on milk production of dairy heifers.

administration was discontinued while the animal was still under the influence of growth hormone, a sudden drop in production resulted. Rapid declines in lactation were observed when the crude extract was administered. It is of interest to note that one of the heifers in this group reached a daily production of 14.7 lb. of milk, the highest peak recorded in this series of heifers.

It can be seen by observation of Figure 3 that thyrotropin was efficacious in causing an increase in milk yield in three of the four heifers to which it was given. When the thyrotropin was discontinued and growth hormone was administered, an additional response occurred. Again, when the crude extract was given, no stimulatory effect was noted.

The pituitary preparation that produced the most marked effects on lactation was the growth hormone. Increases in production occurred whenever it was given (Figures 1, 2 and 3). Since the growth preparations used were contaminated with considerable amounts of thyrotropin, it is possible that the increase in production elicited from the growth preparation was due in part to the T.S.H. in it. It is interesting to note, however, that when the thyrotropic hormone was followed by the growth factor (Figure 3), a definite additional impetus was provided by the growth preparation.

This marked stimulation by the growth hormone is in agreement with the results of others. In injection experiments on lactating cows, Cotes *et al.* (1) obtained definite galactopoietic activity by administration of growth hormone. Using this A. P. hormone alone, they obtained increases in production very close in value to those obtained by administering unfractionated ox A. P. extracts. Donker and Petersen (3) also have found that growth hormone greatly increased milk production in dairy cows.

The effect of the administration of crude pituitary extract to dairy heifers is not clear from this experiment. In some heifers production went down when the crude extract was given; in others no such decline occurred.

A comparison of the production records of the heifers based upon their initial treatment is of interest. It can be seen by examination of the production graphs that the lactation response to injected pituitary hormones was usually much greater in the heifers primed with stilbestrol alone (solid lines) than in those that received a combination of stilbestrol and progesterone (broken lines). This result is somewhat surprising, since in our previous work (4) we found the tissue produced by stilbestrol alone to be less normal histologically than that produced by a combination of stilbestrol plus progesterone or stilbestrol plus anterior pituitary extract. Cowie *et al.* (2) also have observed that the lactations of goats primed with estrogen and progesterone were no better than those of goats primed with estrogen alone.

Histological examination of the udder tissue from the present experiment revealed no striking variations. In general, the microscopic picture was similar to that of a normal lactating animal. A few sections showed a lack of alveoli formation, there being instead a predominance of terminal duct tissue. Also, in some instances alveoli were rather widely distended. These effects, however, were present to some extent in all groups and do not seem to be correlated with the injection pattern. It appears that if histologically different types of tissue existed when pituitary hormone treatment was instituted—and both our previous work (4) and that of Cowie *et al.* (2) indicates that such was the case—this difference was corrected by the administration of pituitary hormones during lactation. Our previous work had given some slight indication that less abnormal tissue was developed when pituitary extracts were administered with stilbestrol during hormonal development of the udders of heifers.

SUMMARY AND CONCLUSIONS

The lactation response of dairy heifers to the injection of anterior pituitary hormones has been investigated. Milk production was found to be much greater in heifers in which the udder was developed with stilbestrol than in heifers in which a combination of stilbestrol and progesterone was used. Prolactin had only a slight stimulatory effect, if any, upon the induced lactations. Thyrotropic hormone was found to stimulate lactation markedly. The most stimulation, however, was obtained by the administration of a growth hormone preparation. These effects were partly a result of thyrotropic hormone contamination of this pre-

paration, but our experiments indicate that growth hormone per se has galactopoietic effects.

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A HIGH ROUGHAGE SYSTEM FOR RAISING CALVES BASED ON THE EARLY DEVELOPMENT OF RUMEN FUNCTION. II. GROWTH, FEED CONSUMPTION, AND UTILIZATION BY CALVES FED A 3:2 RATIO OF HAY TO GRAIN WITH OR WITHOUT MOLASSES OR PENICILLIN SUPPLEMENT

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The background and details of the high roughage system for raising calves based on the early development of rumen function have been described in a previous paper (3). Early rumen function in this system was encouraged by feeding large amounts of good hay with limited grain and milk plus rumen inoculations, using cud material freshly obtained from older cattle, to supply an early, reliable source of rumen microorganisms. Further work is being carried out to study various modifications of the high roughage system with the aim of securing the most economical growth and efficiency of feed utilization with maximum dependence upon rumen function.

Klosterman *et al.* (4) have shown that cane molasses or molasses ash, when added to a fattening ration for beef cattle, where late cut timothy hay and corn cobs were the only roughages, resulted in increased average daily gains. The addition of alfalfa meal, alfalfa ash, a trace mineral mixture containing iron, copper, cobalt, manganese and zinc or 8 lb. of corn silage daily also resulted in increased averge daily gain of steers fed the poor quality roughage. As molasses is a popular constituent of calf rations often added to increase palatability, it seemed desirable to test the value of molasses in the ration of young calves when fed good quality alfalfa hay in this system.

Several reports have been made showing that penicillin provides a growth stimulant and increases feed efficiency when added to the rations of swine (1,2,6). Knodt and Bloom, however, found a decrease in rate of gain and starter consumption in dairy calves when 0.5 g. of potassium penicillin was added per 100 lb. of milk replacement (5).

In a previous experiment (3) no increase in growth of high roughage fed calves was found to result from feeding A.P.F. supplement No. 3 (Merck), a vitamin B_{12} supplement. Also, the performance of high roughage fed calves raised on either a 2:1 or a 4:1 ratio of hay to grain was presented (3).

In this study a comparison was made between Jersey and Holstein calves fed a 3:2 ratio of hay to grain to 12 weeks of age. A comparison was made also of the effects of adding either molasses or penicillin to the 3:2 hay to grain ration on the performance of Jersey calves. An additional comparison was made between Jersey and Holsteins for the entire 6-month period when fed the 3:2 ratio of hay to grain to 12 weeks of age followed by a 2:1 ratio of hay to grain to 26 weeks of age.

Received for publication July 8, 1953.

EXPERIMENTAL PROCEDURES AND RESULTS

Experiment No. 1: Performance of Jersey and Holstein calves fed a 3:2 ratio of hay to grain. Two groups of calves, six Jerseys (3 ♀, 3 ♂) and six Holsteins (3 ♀, 3 ♂) were used in this experiment. After a 3-day colostrum feeding period, whole milk was fed at the rate of 1 lb. per 10 lb. of birth weight daily, using Jersey milk for Jersey calves and Holstein milk for Holstein calves. Milk feeding was terminated at the end of the 7th week. As soon as the calves were removed from their dams, a dry feed mixture was offered free choice. The mixture consisted of 60% mixed legume-grass hay (one-half second cutting alfalfa timothy and one-half second cutting clover timothy) coarsely ground in a hammer mill using a ¾ in. screen; 15% ground shelled corn; 10% soybean oil meal; and 15% molasses concentrate ("Mo-Con" containing 49% molasses solids, 45% brewers' grains, 6% moisture), making a 3:2 ratio of hay to grain concentrates. The entire mixture contained an average of 13.6% total protein, 5.7% ash and 17.7γ per gram carotenoids. All calves were rumen inoculated as previously described (3) at the end of the 1st week and weekly thereafter for 6 weeks. Each calf was given a 250,000 unit vitamin A capsule at the end of each of the first 4 weeks to assure an adequate vitamin A intake. Daily records were kept of feed consumption. Water was supplied ad libitum. The calves were weighed at birth and at weekly intervals thereafter.

Feed consumption, growth, and efficiency of feed utilization calculated as TDN and NE per pound gain for the 12-week period are shown in Table 1. Figure 1 shows the weekly changes in body weight for the 12-week period, compared to the Ragsdale standard (8). The average weekly consumption of the 3:2 hay to grain mixture is shown in Figure 2.

Experiment No. 2: Effect of penicillin or molasses supplement on performance of calves fed a 3:2 ratio of hay to grain. The 18 Jersey calves used in this experiment were divided into two groups at birth. The system of feeding and management used and the basic dry feed ration (3:2 hay to grain ratio) was the same as that fed in Experiment 1. One group of ten calves (6 ♂, 4 ♀) received the same dry feed mixture described in Experiment 1, and the other group of eight calves (5 ♂, 3 ♀) received a similar mixture except that the 7.5 lb. of molasses solids was

TABLE 1

Performance of Jersey and Holstein calves fed a 3:2 ratio of hay to grain to 12 weeks of age

	Jerseys	Holsteins
No. and sex of calves	6 (3♀, 3♂)	6 (3♀, 3♂)
Whole milk *(lb.)*	230	418
3 hay : 2 grain mix *(lb.)*	133	203
Birth wt. *(lb.)*	51	102
Weight at 12 wk. *(lb.)*	108	192
Gain, 12 wk. *(lb.)*	57	90
Gain, 12 wk. *(%)*	112	88
TDN/lb. gain *(lb.)*[a]	2.10	2.14
NE/lb. gain *(Therms)*[a]	2.08	2.16

[a] TDN and NE calculated from Morrison's (7) appendix, Tables 1 and 2.

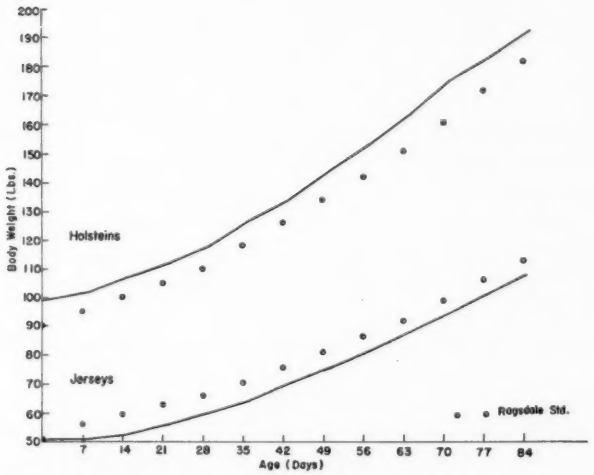

FIG. 1. Weekly changes in body weight during the first 12 weeks of 6 (3♀, 3♂) Holstein and 6 (3♀, 3♂) Jersey calves fed a mixture of 3 parts ground hay to 2 parts grain concentrates containing molasses (Experiment 1), compared to the Ragsdale standard for heifers.

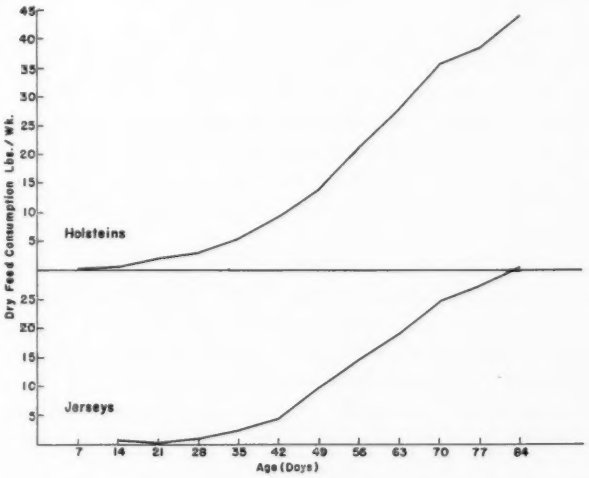

FIG. 2. Average weekly dry feed consumption during the first 12 wk. of 6 (3♀, 3♂) Holstein and 6 (3♀, 3♂) Jersey calves fed a mixture of 3 parts ground hay to 2 parts grain concentrate containing molasses (Experiment 1).

replaced with an equal amount of ground shelled corn. The two mixtures were of the following composition:

	Molasses *(lb.)*	No Molasses *(lb.)*
Mixed second cutting legume, grass hay (coarsely ground)	60	60
Ground shelled corn	15	22.5
Soybean oil meal	10	10
Molasses concentrate:		
Dried brewer's grains	7.5	7.5
Molasses solids	7.5	——

Average chemical composition was the same as the ration described in Experiment 1.

Half of the calves in each group (5 ♂, 4 ♀) were also given 0.1 g. of procaine penicillin per 100 lb. of feed dry matter (0.9 mg. per day in the milk during the 7-week milk feeding period and 1.0 mg. per pound of dry feed mixture from the end of the 7th week to 12 weeks of age). The other half served as controls (6 ♂, 3 ♀). All calves in both groups were also given 1.82 g. of A.P.F. supplement No. 3 (Merck) containing 50γ of vitamin B_{12} daily in the milk, and the same amount was added to each pound of the dry feed mix after the milk feeding period. The vitamin B_{12} supplement was added to eliminate any possible deficiency of this vitamin.

All calves were weighed and measured at birth and weekly thereafter for the 12-week experimental period. Daily records were kept of feed consumption. Table 2 shows the average feed consumption, growth and efficiency of feed utilization calculated as TDN and NE per pound of gain for the 12-week period.

Six of the seven Jersey heifers in Experiment 2 and the six Holsteins (3 ♀, 3 ♂) in Experiment 1 were continued on experiment to 6 months of age. They were fed a 2:1 ratio of alfalfa hay and a simple grain mixture (20% protein) from 12 to 26 weeks of age.

Table 3 shows the performance of these calves for the entire 6-month period as measured by feed consumption, growth, TDN, and NE per pound of gain. The average efficiency of feed utilization measured by TDN and NE per pound of gain during the period 18-26 weeks also is shown in Table 3. This 9-week period was arbitrarily selected as in a previous report (3) because all calves were being fed alike during this period on the 2:1 ratio of hay to grain and were considered to be relatively free from any possible differences due to treatment prior to 12 weeks of age.

DISCUSSION

Although large differences in feed consumption and growth were observed between the Jerseys and Holsteins (Tables 1 and 3), the average efficiency of feed

TABLE 2

Effect of adding a molasses concentrate with or without penicillin on the performance of Jersey calves fed a 3:2 ratio of hay to grain during the first 12 weeks

	Molasses		No molasses					
	Penicillin	No penicillin	Penicillin	No penicillin	Penicillin[b]	No penicillin[c]	Molasses[d]	No molasses[e]
No. and sex of calves	5 (2♀, 3♂)	5 (2♀, 3♂)	4 (2♀, 2♂)	4 (1♀, 3♂)	9 (4♀, 5♂)	9 (3♀, 6♂)	10 (4♀, 6♂)	8 (3♀, 5♂)
Whole milk *(lb.)*	228.1	212.2	229.3	220.0	228.6	215.6	220.1	224.6
3 hay : 2 grain mixture *(lb.)*	120.8	125.6	127.3	116.6	123.8	121.6	123.2	122.1
Birth wt. *(lb.)*	52	52	56	58	54	55	52	57
Body wt. at 12 wk. *(lb.)*	105	103	111	105	108	104	104	108
Gain, 12 wk. *(lb.)*	53	51	55	47	54	49	52	51
Gain, 12 wk. *(%)*	101.9	98.1	98.2	81.0	100.0	89.1	100.0	89.5
Birth withers ht. *(in.)*	25.7	25.9	25.7	26.4	25.7	26.2	25.8	26.1
Height, 12 wk. *(in.)*	29.8	29.0	30.1	29.7	29.9	29.3	29.4	29.9
Gain in ht., 12 wk. *(in.)*	4.1	3.1	4.4	3.3	4.2	3.1	3.6	3.8
Gain in ht., 12 wk. *(%)*	16.0	12.0	17.1	12.5	16.3	11.8	14.0	14.6
TDN/lb. gain *(lb.)*[a]	2.14	2.20	2.12	2.29	2.13	2.24	2.17	2.21
NE/lb. gain *(Therms)*[a]	2.14	2.16	2.12	2.31	2.13	2.23	2.15	2.22

[a] TDN and NE calculated from Morrison's (7) appendix, Tables 1 and 2.
[b] Columns 1 and 3 combined.
[c] Columns 2 and 4 combined.
[d] Columns 1 and 2 combined.
[e] Columns 3 and 4 combined.

TABLE 3

Performance of Jersey and Holstein calves fed a 3:2 ratio of hay to grain to 12 weeks and a 2:1 ratio from 12 to 26 weeks

	Jerseys	Holsteins
No. and sex of calves	6(♀)	6 (3♀, 3♂)
Whole milk *(lb.)*	212	418
Total hay *(lb.)*	537	850
Total grain *(lb.)*	281	439
Birth wt. *(lb.)*	51	102
Wt. at 6 mo. *(lb.)*	240	413
Gain, 6 mo. *(lb.)*	189	311
Gain, 6 mo. *(%)*	371	303
Birth wither ht. *(in.)*	25.8	29.5
Ht., 6 mo. *(in.)*	35.0	39.8
Gain in ht., 6 mo. *(in.)*	9.2	10.3
Gain in ht., 6 mo. *(%)*	35.7	34.9
TDN/lb. gain, 6 mo. *(lb.)*[a]	2.76	2.72
NE/lb. gain, 6 mo. *(Therms)*[a]	2.57	2.69
TDN/lb. gain, 18-26 wk. *(lb.)*[a]	3.21	3.20
NE/lb. gain, 18-26 wk. *(Therms)*[a]	2.81	2.89

[a] TDN and NE calculated from Morrison's (7) appendix, Tables 1 and 2.

utilization as indicated by TDN and NE per pound of gain was not markedly different.

Weekly changes in growth and dry feed consumption of the calves in Experiment 1 during the first 12 weeks are shown in Figures 1 and 2. It is of interest to note that the Jersey calves fed the 3:2 hay to grain mixture maintained approximately the same relationship to the Ragsdale growth standard as the calves fed a 4:1 hay to grain mixture, as previously reported (3). Further work is being done, in which direct comparisons of different proportions of hay to grain are being made.

As shown in Table 2, no advantage was found in adding the molasses concentrate to the 3:2 hay to grain mixture. Although the penicillin-fed calves gained slightly more in body weight and withers height and were slightly more efficient in feed utilization than the molasses fed calves, these differences were not statistically significant and are not conclusive. The calves in this experiment (No. 2) grew slightly less than the Ragsdale standard, based on both body weight and height at withers. Furthermore, a comparison of the average increase in height at withers, at 3 and 6 months of age (Tables 2 and 3), with the Ragsdale standard shows that both the Jerseys and Holsteins gained slightly less than the standard. Experiments are now in progress to determine whether better skeletal growth may be obtained by more liberal milk feeding during the early weeks without interfering with the development of early rumen function.

SUMMARY AND CONCLUSIONS

A comparison was made of the performance of Jersey and Holstein calves raised according to the high roughage system, using a mixture of three parts coarsely ground mixed legume and grass hay and two parts of a simple grain con-

centrate mixture as the dry feed in the ration to 12 weeks of age. A 2:1 ratio of hay to grain was fed from 12 weeks to 26 weeks of age. Growth as indicated by body weight and height at withers was slightly less than the Ragsdale standards. No difference in efficiency of feed utilization was noted between the Jerseys and Holsteins during the first 12 weeks, the period 18-26 weeks, or the entire 6-month period.

No significant benefit resulted from adding either molasses or penicillin to the 3:2 hay to grain ration as measured by growth, feed consumption, or efficiency of feed utilization in the Jersey calves.

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance of John E. Tate, Hershel D. Miller and Ross L. Johnson in conducting these experiments.

The molasses concentrate "Mo-Con" was supplied by Standard Brands, Inc., New York, N. Y. The vitamin A capsules were supplied by the R. P. Scherer Corp., Gelatin Products Division, Detroit, Mich. The vitamin B_{12} supplement was supplied through the courtesy of Merck and Co., Rahway, N. J.

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A HIGH ROUGHAGE SYSTEM FOR RAISING DAIRY CALVES BASED ON THE EARLY DEVELOPMENT OF RUMEN FUNCTION. III. EFFECT OF RUMEN INOCULATIONS AND THE RATIO OF HAY TO GRAIN ON DIGESTION AND NITROGEN RETENTION

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The development of the high roughage system for raising dairy calves offers a means for taking early advantage of the inherent capacity of the young ruminant to consume and digest large amounts of roughage (7, 8). This system is characterized by limited milk and grain feeding with large amounts of good quality roughage. Rumen inoculations with freshly obtained cud material from older cattle were used to supply an early source of typical adult-type rumen microorganisms. In this way healthy calves can be raised at low cost by utilizing mostly home grown feeds. (8).

The digestion of cellulose and other plant carbohydrates probably is the most important digestive function of the rumen because it enables ruminants to utilize several otherwise indigestible materials as sources of energy.

It has been known for some time that crude fiber digestibility is decreased when high levels of readily fermentable carbohydrates are included in the ration (12). In vitro investigations by Arias *et al.* (1) using an artificial rumen showed that a small quantity of starch enhanced cellulose digestion by rumen microorganisms; however, further increases impaired digestion.

Previous work (3) indicated that maximum digestibility of cellulose in calves fed high roughage rations was attained at an earlier age in rumen inoculated calves than in uninoculated calves segregated from older animals. Other factors affecting crude fiber digestion are covered in the review by Mangold (12).

There are several recent reports which suggest the important role of rumen microorganisms and constituents of the ration in ruminant digestion and utilization of protein and nonprotein nitrogen. For example, it has been shown that the extent to which proteins are hydrolyzed and deaminated in the rumen is dependent upon the nature of the protein itself (5, 14) and that the utilization of nonprotein nitrogen in the rumen by microorganisms was increased by the presence of readily available carbohydrate in the feed (16, 17). Also, Loosli *et al.* (11) have shown that urea nitrogen can be utilized by rumen bacteria to synthesize the essential amino acids. Since an excellent review of nitrogen metabolism in ruminants has been made by McNaught and Smith (16), further discussion will not be included here.

The experiments described in this paper were carried out to determine the

Received for publication July 8, 1953.

[1] The material herein reported was taken from a dissertation presented by the senior author to the graduate faculty of The Ohio State University in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

effect of rumen inoculations and the ratio of hay to grain eaten on the dry matter, cellulose, and protein digestion and nitrogen retention of high roughage fed calves. These factors were studied since it seemed probable, based on previous work (8, 19, 20), that the availability of rumen microorganisms and the type of feed fed were the principal factors involved in the establishment of early rumen function in calves.

EXPERIMENTAL PROCEDURES

The dry matter was determined by oven drying and the total nitrogen by the Kjeldahl method. Cellulose was determined by the method of Crampton and Maynard (4).

The feeding schedule of the calves was adjusted to a constant level during the week preceding the 5-day collection periods.

All digestion experiments were carried out in metabolism stalls in which urine was dropped through an expanded metal bottom onto a sloping sheet metal trough coated with paraffin which carried the urine into collection bottles. The expanded metal bottoms were covered with synthetic rubber fabric, "Neomat," in order to make the stalls more comfortable for the calves. Feces were collected in triangular bags fabricated from a rubberized cloth and attached to a light canvas calf blanket, as described previously (3). Pliofilm turkey storage bags were used as insert liners. This modification eliminated the need for removal of the bag for washing each day, helped prevent any loss of feces from the cloth bag, and facilitated handling and mixing of the feces. The Pliofilm bags were washed after using and reused.

Feces and urine were collected daily and aliquots taken for chemical analyses. Samples for nitrogen determinations were preserved with hydrochloric acid.

Jersey bull calves from the Ohio Agricultural Experiment Station herd which had been raised on various modifications of the high roughage system, as described by Hibbs *et al.* (8), were used as experimental animals. After a 3-day colostrum-feeding period, whole milk was fed at the daily rate of 1 lb. per 10 lb. of birth weight for the first 6 weeks and reduced to zero by the end of the 7th week. Good quality hay was fed free choice from the start and grain limited to various proportions of hay eaten. The grain concentrate was made up of a mixture of 73% ground shelled corn and 27% soybean oil meal and contained 18.1% crude protein. Rumen inoculations, except in uninoculated calves, were given weekly for the first 6 weeks to supply an early reliable source of rumen microorganisms. Vitamin A capsules containing 250,000 I.U. each were administered at the end of the 1st week and weekly thereafter for 4 weeks in order to eliminate any possible vitamin A deficiency. The calves were housed in a well ventilated, temperature regulated barn equipped with individual stalls.

Rumen inoculated vs. uninoculated calves. In Experiments 1 and 2 an attempt was made to study the differences in digestibility and nitrogen retention between rumen inoculated and uninoculated, high roughage fed calves.

The uninoculated calves were segregated from other cattle, and precautions were taken to prevent contamination of feed and water buckets with rumen microorganisms during feeding. Rumen samples for microscopic examination were

taken by stomach tubes at 6, 9, and 12 weeks of age and during or preceding digestion experiments.

In Experiment 1, four Jersey bull calves were paired on the basis of similar birth weight and age. One calf of each pair was kept uninoculated. Both before and during the digestion trials good quality, second-cutting, coarsely ground alfalfa hay mixed with the grain concentrate in the proportion of four parts hay and 1 part grain was fed. Digestion trials were conducted during the 11th and 12th weeks of age. Dry matter, cellulose, and apparent protein digestion and nitrogen retention were measured. Pair No. 2 was removed from the experiment during the 12th week, since certain characteristic rumen organisms had begun to appear by this time in the uninoculated calf.

At 13 weeks of age pair No. 1 was changed to an 11.1% protein ration made up of 66% poor quality timothy hay, 24% soybean oil meal, and 10% ground shelled corn. Digestibility and nitrogen balance studies were made during the 16th and 20th weeks. The uninoculated calf (968) was then rumen inoculated during the 21st week, and digestibility and nitrogen balance were measured again during the 25th week.

In Experiment 2, a pair of Jersey bull calves (one inoculated and the other uninoculated) was used to study the effect of rumen inoculations on digestibility using higher proportions of grain to hay. Digestibility and nitrogen retention were measured during the 9th and 13th weeks, while the calves were being fed a ratio of three parts hay to two parts of the 18.1% protein grain mixture. The calves were then changed to a ration of two parts good quality chopped clover-timothy hay and three parts of the same grain mixture. After a 2-week preliminary period, digestion trials were carried out. Following these trials the calves were changed to a ration of three parts mature timothy hay and two parts 18.1% protein grain mixture. At the end of a 3-week preparatory period, a 10-day digestion trial and urine collection period concluded Experiment 2.

Effect of the proportion of hay to grain. In Experiment 3, good quality, coarsely ground alfalfa hay was mixed with grain concentrate in the following ratios of hay to grain: 4:1, 3:2, and 2:3. These mixtures were fed free choice from birth. During the 13th week of age, feces and urine collections were made on the three calves assigned to each group for digestion and nitrogen balance determinations.

The above experiment was duplicated using second cutting mixed clover-timothy hay. At the conclusion of the digestion trials, two calves from the group receiving the 2:3 ratio of hay to grain were abruptly changed to a 4:1 hay to grain ratio, and after 3 days urine and feces were collected for two consecutive 5-day periods.

RESULTS AND DISCUSSION

The results of Experiments 1 and 2 showing the influence of rumen inoculation on the apparent digestibility of protein and nitrogen retention in high-roughage fed calves are presented in Table 1. The apparent digestion of protein was markedly increased by rumen inoculations on the lower protein rations or when

the protein source was largely alfalfa hay. This is indicated by the higher digestion coefficients for calf 965 (inoculated, 64.7-67.8) compared to 968 (uninoculated, 54.4-61.8). When calf 968 was later inoculated, the apparent protein digestibility was found to be equal to that previously found for calf 965 on the same ration. Routine microscopic examinations of the rumen contents of both the inoculated and uninoculated calves showed the uninoculated calf to be free of protozoa and several of the indicator microorganisms described by Pounden and Hibbs (19).

The increase in protein digestibility may have been associated with the marked difference in the types of rumen microorganisms observed. It is of interest that Pounden *et al.* (18) found that protozoa and hay-group No. II bacteria, which were absent in the uninoculated calf (968) were among the rumen microorganisms most readily digested in the abomasum and small intestines. Therefore, a possible explanation of the difference observed in apparent protein digestibility between the cud inoculated and the uninoculated calf may have been a difference in digestibility of rumen microorganisms.

The apparent increased rate of absorption of nitrogen seemed to have little measurable effect on the daily nitrogen retention. Although the average level of retention was slightly higher in the inoculated calf (965), the results were variable among trials, and inoculation of the uninoculated calf (968) did not

TABLE 1

The influence of rumen inoculations on the excretion and retention of nitrogen in young calves

Calf No.	Trial No.	Type of hay fed	Hay : grain ratio	Protein in ration	Nitrogen intake	Nitrogen urine	Nitrogen feces	Daily N · retention	Protein digested	Remarks
				(%)	*(g.)*	*(g.)*	*(g.)*	*(g.)*	*(%)*	
					Experiment 1					
965	1	Alf.	4:1	14.1	222.2	117.8	72.1	4.61	67.8	Inoculated
968	1	Alf.	4:1	14.1	226.4	96.5	86.5	6.22	61.8	Uninoculated
965	2	Tim.	2:1	11.1	163.8	86.0	51.7	7.35	64.7	Inoculated
968	2	Tim.	2:1	11.1	157.5	67.6	71.8	5.45	54.4	Uninoculated
965	3	Tim.	2:1	11.6	171.3	99.8	59.0	4.87	65.5	Inoculated
968	3	Tim.	2:1	11.6	163.8	94.7	72.6	−0.51	55.7	Uninoculated
965	4	Tim.	2:1	11.6	229.7	138.6	69.5	4.33	69.2	Inoculated
968	4	Tim.	2:1	11.6	239.5	149.3	81.7	1.69	65.9	Inoculated[a]
					Experiment 2					
976	1	Alf.	3:2	15.2	224.9	96.7	58.7	13.9	73.8	Inoculated
977	1	Alf.	3:2	15.2	198.6	79.7	63.5	10.7	67.6	Uninoculated
976	2	Alf.	3:2	15.2	282.8	114.1	84.9	16.8	70.0	Inoculated
977	2	Alf.	3:2	15.2	282.8	90.7	85.4	21.3	69.8	Uninoculated
976	3	Cl-Tim.	2:3	15.4	322.6	97.7	106.8	23.6	66.8	Inoculated
977	3	Cl-Tim.	2:3	15.4	343.2	113.3	112.8	23.4	66.9	Uninoculated
974	4[b]	Cl-Tim.	3:2	11.2	517.1	213.7	194.8	9.9	62.4	Inoculated
977	4[b]	Cl-Tim.	3:2	11.2	510.3	177.0	212.5	11.1	58.8	Uninoculated

[a] Cud inoculated 3 wk. prior to trial 4.

[b] 10-day trials — others were 5-day trials.

seem to have an appreciable effect on daily nitrogen retention. It is also shown in Table 1 that most of the additional nitrogen absorbed by the rumen inoculated calf was excreted in the urine. For example, the rumen inoculated calf absorbed an average of 19.5 g. of nitrogen per trial more than the uninoculated calf, but it also excreted 15.0 g. more in the urine. This indicated that a large proportion of the additional amino acids absorbed by the inoculated calf were deaminated and the nitrogen excreted in the urine possibly because the level of energy in the ration limited the amount of nitrogen retained by the calves.

Differences in apparent digestion of protein between inoculated and uninoculated calves were eliminated when the proportion of hay to grain was changed from the 4:1 ratio to a ratio of 3:2 or 2:3 (Experiment 2, Table 1). Changing to a low-protein grain concentrate and timothy hay ration with a higher proportion of grain gave a less marked difference between the inoculated and the uninoculated calf than had been observed in Experiment 1 (Table 1), when less grain was fed in proportion to hay.

The results of the nitrogen retention and protein digestion measurements in Experiment 3 are summarized in Table 2. The apparent digestibility of protein increased when higher proportions of grain concentrates were included in the

TABLE 2

The influence of the type of hay fed and the ratio of hay to grain on the digestibility of cellulose, dry matter, protein and daily nitrogen retention in 12-week-old calves

No. of calves	Kind of hay fed[a]	Hay : grain ratio	Dry matter	Cellulose	Protein	Daily nitrogen retention
			(%)	*(%)*	*(%)*	*(g./100 lb.)*
3	Alf.	4:1	66.0	65.6	66.8	7.13
3	Alf.	3:2	68.9	70.5	71.6	12.90
3	Alf.	2:3	72.5	60.3	72.3	13.02
3	Cl-Tim.	4:1	66.6	69.2	57.7	7.77
3	Cl-Tim.	3:2	69.0	68.9	60.2	10.84
3	Cl-Tim.	2:3	70.1	60.1	67.1	12.72

[a] Alfalfa hay — second cutting (13.5% protein)
Clover-Timothy hay — second cutting (11.5% protein)

ration. The average coefficient of digestibility of protein was found to be considerably higher when alfalfa hay was utilized as the roughage than when a mixed clover-timothy hay was used.

A possible explanation of the difference in protein digestibility between the two types of hay fed is indicated by the work of McDonald (13). He has shown that significant amounts of ammonia nitrogen produced by the deaminating activity of rumen microorganisms are lost by direct absorption through the rumen wall into the portal blood stream and by ultimate excretion into the urine. Furthermore, the amount of ammonia lost by this route is associated with the nature of the protein source of the ration (5). Therefore, the higher digestion coefficients for alfalfa hay may be the result of greater loss of ammonia from the rumen.

The average nitrogen retention of the calves receiving the 4:1 ratio of hay to

grain was significantly less than the average of the group receiving either the 3:2 or 2:3 ratio ($P < 0.05$). No statistically significant differences were observed between the nitrogen retention in groups fed the 3:2 or 2:3 ratios of hay to grain.

Reports in the literature indicate that the available energy in the feed was a possible limiting factor for nitrogen retention in the calves fed the 4:1 ratio. Early work by Kuhn *et al.* (9) showed that the addition of starch meal to an all roughage ration low in readily digestible nutrients increased nitrogen retention. Lofgreen *et al.* (10) demonstrated a direct influence of the energy level in the feed on the rate of nitrogen retention in calves. Although protein level in the 2:3 hay to grain ration was higher than in the 4:1 ration (Table 3), it is likely that the higher nitrogen retention in the 2:3 ration was due principally to the higher energy intake. This is further supported by the results of Hibbs *et al.* (8) who have shown that replacing a 14.5% protein grain ration with a 25% ration in calves fed 2 parts hay to 1 part grain did not result in increased weight gains. Also, as mentioned above, the higher level of protein fed in the alfalfa ration in Experiment 3 (Table 2) failed to produce a higher rate of daily nitrogen retention than the clover-timothy ration.

A decreased digestion of cellulose was observed when the 2:3 ratio of hay to grain was compared to the 3:2 or 4:1 ratios (Table 2). Other investigators (2, 6) have observed a similar effect from feeding relatively high levels of readily available carbohydrate. The highly significant differences ($P < 0.01$) in cellulose digestion were believed to be associated with the type of rumen flora present. The calves fed on the 2:3 ratio generally did not maintain a well balanced rumen microflora, as judged by the indicator method (19). However, when the calves which were fed the 2:3 ratio of hay to grain were changed abruptly to a ration containing four parts hay to one part grain, the cellulose digestibility raised to the same percentage as that digested by control calves which had been raised on a 4:1 ratio following the milk feeding period (Table 3). The rapidity of the increase in cellulose digestion following the reduction in the proportion of grain to hay suggests that factors other than absence of cellulolytic rumen microorganisms were involved.

This is in support of the suggestion of Arias *et al.* (1) that the rumen bacteria preferentially attack the more readily available carbohydrates in the feed. On the other hand, the decrease in cellulose digestion when the high grain ration (2:3) was fed may have resulted from the failure of cellulose-digesting microorganisms to grow at an optimum rate when the ration contains a high level of grain even though these microorganisms are present. The latter explanation is supported by the observation that some of the characteristic microorganisms being used as indicators of typical mature type rumen flora and fauna were not consistently established in the rumens of calves fed hay and grain in ratios of more than one part grain to one part hay, even though a balanced flora and fauna were provided by use of rumen inoculations with cud material from older cattle (20).

Two cud inoculated calves and two uninoculated calves in Experiment 1 were fed four parts alfalfa hay and one part of the 18.1% protein grain mixture. The

TABLE 3

The influence of the ratio of hay to grain fed and of changing from a high grain ration to a high roughage ration on the digestion of dry matter, cellulose and protein and daily nitrogen retention

Calf No.	Hay : grain ratio	Daily NE intake[a]	Daily crude protein intake	Dry matter digested	Cellulose digested	Protein digested	Daily nitrogen retention	Remarks
		(therms/100 lb.)	*(g./100 lb.)*	*(%)*	*(%)*	*(%)*	*(g./100 lb.)*	
993	4:1	1.71	203	69.4	68.9	57.5	8.52	Fed high roughage ration (4:1) continuously.
997	4:1	1.59	187	68.0	68.9	61.5	7.04	
Av.		1.65	195	68.7	68.9	59.5	7.78	
994	2:3	2.05	226	68.6	61.4	66.8	13.49	Fed high grain ration (2:3) continuously to 13 wk.
996	2:3	2.14	234	69.7	59.7	64.4	10.06	
Av.		2.10	230	69.2	60.6	65.6	11.78	
994	4:1	1.76	206	64.5	70.4	55.1	6.74	Digestion trials begun 3 days after changing from the 2:3 to the 4:1 ratio of hay to grain.
996	4:1	1.73	202	65.3	69.6	55.9	8.29	
Av.		1.75	204	64.9	70.0	55.5	7.52	
994	4:1	1.76	206	66.9	70.8	60.2	9.46	Digestion trials begun 8 days after changing from the 2:3 to the 4:1 ratio of hay to grain.
996	4:1	1.73	202	65.0	68.8	58.7	9.03	
Av.		1.75	204	66.0	69.7	59.4	9.26	

[a] Calculated from Morrison's *Feeds and Feeding*, 21st. ed., appendix, Table 2.

inoculated calves digested dry matter at the rate of 63.4%, and the uninoculated calves at 60.0%. Cellulose digestibility was 64.4% for the inoculated calves and 61.3% for the uninoculated calves.

The utilization of cellulose and protein was markedly influenced by the proportion of grain to hay in the ration. When both cellulose and nitrogen retention are taken into consideration, it appears that the 3:2 ratio of hay to grain was superior to either the 4:1 or the 2:3 hay to grain ration for high roughage fed calves.

SUMMARY

The digestibility of protein, dry matter, and cellulose and nitrogen retention have been studied in rumen inoculated and uninoculated calves and in calves fed various types of hay and grain in the ratios of 4:1, 3:2, and 2:3.

Cud inoculations increased the apparent digestibility of protein in a calf when a low protein, poor quality hay ration was fed or when the chief source of protein was alfalfa hay. Increased protein through heavier grain feeding did not result in a difference in protein digestibility between cud inoculated and uninoculated calves.

Nitrogen retention was not significantly affected by rumen inoculations.

Alfalfa and mixed clover-timothy hay fed in combination with a mixture of corn and soybean oil meal in the ratio of four parts hay to one part grain resulted in the low nitrogen retention of 7.45 g. per day per 100 lb. of body weight. When hay-grain ratios of 3:2 and 2:3 were fed, the average retention was 11.87 and 12.87 g. of nitrogen per 100 lb. of body weight per day, respectively. The average daily nitrogen retention for the two types of hay was approximately the same even though the apparent digestibility of alfalfa hay was markedly higher than that of the mixed clover-timothy.

The digestibility of cellulose was less when the 2:3 ratio of hay to grain was fed than when either 4:1 or 3:2 ratios were fed, regardless of the type of hay used. Calves changed abruptly from a 2:3 to a 4:1 ratio digested cellulose equally as well as control calves fed continuously on a 4:1 ratio.

The implications of these results are discussed in relation to rumen physiology and their application to the high roughage system of calf feeding.

ACKNOWLEDGMENTS

The authors wish to acknowledge the technical assistance of R. G. Washburn, E. G. Linke, and John E. Tate in conducting this investigation.

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FINAL REPORT OF THE CURRICULUM COMMITTEE

A committee, appointed in 1949 by President Becker and continued by Presidents Bendixen and Henderson, was asked to study the curricula for Dairy Manufacturing and Dairy Production as offered at the various agricultural colleges and to make recommendations as to desirable curricula and content of courses for these two fields at both the graduate and undergraduate level. The work was divided among the following subcommittees: I. Basic Sciences; II. Dairy Production Majors; III. Dairy Manufacturing Majors; IV. General Education, and V. Graduate Studies. Each subcommittee had as its chairman a member of the Curriculum Committee who chose his committee members. Each subcommittee was asked to suggest a list of required and recommended courses for a technical and a nontechnical curriculum for dairy manufacturing majors and for dairy production majors.

PROCEDURE

In 1949 a questionnaire was sent by the chairman to all the Land-Grant Colleges in the United States plus two other agricultural colleges and to seven Canadian universities teaching agriculture, a total of 57 institutions. Each institution was asked to list its course requirements and recommendations for dairy production and dairy manufacturing majors. Fifty-two institutions responded, only one United States institution failing. These data furnished the basis for the work of the subcommittees and the Curriculum Committee.

Each subcommittee formulated its own report, from which the Curriculum Committee prepared over-all curricula. Under comments appear certain suggestions by members of the Curriculum Committee which indicate some differences of opinion.

SUBCOMMITTEE I—*Basic Science Requirements and Recommendations. Technical and Nontechnical Groups.*

	Production majors		Manufacturing majors	
	Required courses	Recommended electives	Required courses	Recommended electives
	Semester credits	Semester credits	Semester credits	Semester credits
MATHEMATICS				
College Algebra	3	—	3	—
Other mathematics at the college level	—	3	—	—
Statistics	—	3	—	—
Trigonometry	—	—	3	—
Analytical Geometry and Calculus	—	—	—	6
PHYSICS				
General Physics, including laboratory	4	—	8	—
CHEMISTRY				
General Chemistry including Qualitative Analysis	8	—	8	—
Organic	6	—	6	—
Animal Biochemistry, including Principles of Nutrition (lecture)	3	—	—	—

	Production majors		Manufacturing majors	
	Required courses	Recommended electives	Required courses	Recommended electives
	Semester credits	Semester credits	Semester credits	Semester credits
Animal Biochemistry, laboratory	2	—	—	—
Advanced Biochemistry	—	3-6	—	—
Biochemistry	—	—	3	—
Quantitative Analysis	—	—	3	—
Dairy Chemistry	—	—	3	—
Physical Chemistry	—	—	—	3
Biocolloid Chemistry	—	—	—	3
ZOOLOGY				
General, including vertebrates	8	—	—	—
Embryology	—	3	—	—
Histology	—	3	—	—
Comparative Anatomy	—	4	—	—
Cytology	—	3	—	—
BOTANY				
General Botany	5	—	—	—
BACTERIOLOGY				
General Bacteriology with full laboratory	4	—	4	—
Dairy Bacteriology	—	—	4	—
Sanitary and Food Bacteriology	—	—	—	3
Microbial Metabolism	—	—	—	3
ANIMAL PHYSIOLOGY				
Physiology of Domestic Animals	5	—	—	—
PARASITOLOGY OR ENTOMOLOGY	—	3	—	—
GENETICS				
Principles of Genetics	4	—	—	—
Advanced Genetics	—	4	—	—
ENGINEERING				
Principles of Dairy Engineering	—	—	3	—
Dairy Machinery	—	—	3	—
TOTAL	52		51	

Recommendation as to course content:

General Physics—Properties of matter, mechanics, heat, light, sound, electricity, and magnetism.

Quantitative Analysis—Including food products of agricultural importance.

Dairy Chemistry—Analysis of milk and its constituents; physical chemistry involved in milk, its processing, and its products.

Zoology—Structure, physiology, classification, and interrelation of animals, with particular reference to the vertebrate body.

General Botany—Morphology, physiology, and genetics of plants.

Principles of Genetics—Introduction to genetics and its application to biology and agriculture.

Principles of Dairy Engineering—Engineering principles, including power supply, refrigeration and heat transfer.

Dairy Machinery—Including machine, equipment and plant design, and plant arrangement.

The subcommittee recommended that, in addition to the courses listed for the Dairy Manufacturing curriculum, the applied service courses should include

chemical and bacteriological laboratory control covering the application of chemistry and bacteriology to dairy processing as a 2-credit course for 1 year. (This is accomplished in Dairy Technology; see later requirements.)

The Curriculum Committee comments are as follows: *Dairy Production curricula*—The basic science requirements seem high for the nontechnical curriculum and might be modified by the elimination for that curriculum of Algebra, Physics, and Botany and changing the credits for several courses as follows: General Chemistry, 6; General Bacteriology, 3; Animal Physiology, 4; and Genetics, 3. *Dairy Manufacturing curricula*—The inclusion of Botany or Zoology as a requirement, the elimination of Dairy Machinery as a requirement, and reducing of Organic Chemistry to 3 or 4 credits seemed desirable.

SUBCOMMITTEE IV—*General Education Requirements and Recommendations. Production and Manufacturing Curricula. Technical and Nontechnical Groups.*

	Required courses	Recommended electives
	Semester credits	Semester credits
ENGLISH		
General Composition	6	—
Speech	—	3
Technical Composition	—	3
Journalism	—	3
ECONOMICS (General)	6	—
AMERICAN HISTORY	3	—
POLITICAL SCIENCE	—	3
SOCIOLOGY	—	3
PSYCHOLOGY		
Introductory	—	3
Psychology of Human Development	—	3
HUMANITIES		
Literary Criticism	—	3
Art History	—	3
History of the Theater	—	3
Appreciation and History of Music	—	3
Elementary Logic	—	3
FOREIGN LANGUAGE		
Elementary Scientific German	—	3
Elementary Scientific French	—	3
Elementary Scientific Spanish	—	3
(18 credits from above recommended list for Production curriculum; 9 credits for Manufacturing curriculum)		
ACCOUNTING	—	4
INDUSTRIAL MANAGEMENT	—	3
PRINCIPLES OF SALESMANSHIP	—	3
RETAIL MERCHANDISING	—	3
MARKETING METHODS	—	3
(9 credits from above recommended list for Manufacturing curriculum)		

Recommendations as to course content:

American History—Special emphasis toward the development of an understanding and appreciation of the concepts and underlying efforts which have made the present United States.

Journalism—Fundamentals of publicity, news writing, and the preparation of copy.

Political Science—Basic principles and institutions of political science with an analysis of the chief problems of American government.

Humanities—Study of great regional cultures, classical or European, in their interrelated aspects: language, literature, geography, history, social institutions, art, and philosophy, as a preparation for living in contemporary society.

Foreign Language—An elementary course to prepare students to translate scientific and technical papers.

Industrial Management—Scientific management; principles of organization; plant location, design, and layout; material handling; procurement; maintenance; store keeping; inventory control, classification, and identification; industrial safety and hygiene.

Retail Merchandising—Principles and problems of management; organization, planning, buying, stock control, sales promotion, personnel administration, store operation, budgeting, and expense control.

SUBCOMMITTEE II—*Dairy Production Majors, Requirements and Recommendations. Technical and Nontechnical Groups.*

	Required courses	Recommended electives
	Semester credits	Semester credits
ANIMAL HUSBANDRY		
Types and Market Classes of Live Stock	3	—
Feeds and Feeding (basic principles)	3	—
Animal Breeding	3	—
AGRONOMY		
Soils	3	—
Forage Crops and Pastures	3	—
Field Crops	—	3
AGRICULTURAL ECONOMICS		
Principles	3	—
Farm Management	—	3
Marketing Farm Products	—	3
ENTOMOLOGY (General)	—	3
AGRICULTURAL ENGINEERING		
Farm Buildings and Equipment	—	3
ANIMAL PATHOLOGY		
Animal Health and Sanitation	—	3
DAIRY PRODUCTION		
Introduction to Dairying	3	—
Dairy Cattle Judging	2[a]	2[b]
Dairy Cattle Feeding	3	—
Dairy Cattle Breeding	3	—
Dairy Herd Management	3	—
Milk Secretion	—	3
Reproduction and Artificial Breeding	—	3
Seminar	1-2	—
DAIRY MANUFACTURING		
Market Milk and Related Products	3	—
Dairy Bacteriology	3[b]	3[a]
TOTAL	34-36	

[a] Nontechnical curriculum.
[b] Technical curriculum.

Recommendations as to course content:

Introduction to Dairying—Economic importance of dairying; composition; chemical and physical properties of milk; sampling and testing milk; principles of the dairy manufacturing processes; breeds of dairy cattle and their characteristics, including selection; simpler procedures for herd management and the production of high quality milk. Includes one laboratory weekly.

Dairy Herd Management—Management for efficient milk production; replacements; breeding and calf rearing; herd health; housing and equipment; production testing and herd records; selling breeding stock; production and marketing of quality milk. Includes one laboratory weekly.

Milk Secretion—Physiology, endocrinology, and biochemistry of milk secretion.

Reproduciton and Artificial Breeding—Physiology of reproduction; problems of fertility; semen production and handling; artificial breeding problems. Includes one laboratory weekly.

An amendment adopted by the Production Section at the 1953 annual meeting was to the effect that a student majoring in dairy production must produce satisfactory evidence that he has had dairy farm experience before being graduated.

Curriculum Committee comments as follows: In view of the fact that Genetics is required, it is suggested that either Animal Breeding or Dairy Cattle Breeding be eliminated as a required course.

SUBCOMMITTEE III—*Dairy Manufacturing Majors, Required and Recommended Courses. Technical and Nontechnical Curricula.*

The courses in agriculture, other than dairy, that meet the minimum requirement of the institution or those listed under Dairy Production curriculum are recommended. The dairy courses are listed below.

	Required courses	Recommended electives
	Semester credits	Semester credits
DAIRY PRODUCTION		
Introduction to Dairying	3	—
Dairy Herd Management	3	—
DAIRY MANUFACTURING		
Dairy Technology	2	—
Advanced Dairy Technology	3	—
Market Milk and Related Products	3	—
Ice Cream and Related Frozen Dairy Products	3	—
Butter Manufacture	3	—
Cheese Manufacture	3	—
Condensed Milk and Dried Milk Products	3	—
Dairy Plant Management	3	—
Dairy Bacteriology (Required in Basic Sciences)	3	—
Advanced Dairy Bacteriology	3[b]	3[a]
Dairy Chemistry (Recommended in Basic Sciences)	3	—
Judging Dairy Products	1	—
Summer Practicum (Required without credit)		

[a] Nontechnical curriculum.
[b] Technical curriculum.

Recommendations as to course content:

Dairy Technology—Principles and practice in the methods of analysis of milk and milk products. A laboratory course.

Advanced Dairy Technology—Function and operation of a dairy control laboratory; methods of analysis of dairy and related products; identification and correction of quality defects in dairy products. Includes two laboratory periods weekly.

Dairy Bacteriology—Importance of microorganisms in dairy products and the determination of the types and numbers as related to quality. Includes one laboratory weekly.

Advanced Dairy Bacteriology—Investigation of techniques for identifying and culturing microorganisms that are of importance to the dairy industry. Includes one laboratory weekly.

Summer Practicum—Work in a processing plant for one summer or its equivalent in practical experience.

The Curriculum Committee comments are as follows: Since Dairy Bacteriology (4 credits) and Dairy Chemistry (3 credits) are required under Basic Sciences, these courses should be eliminated from the requirement under Dairy Manufacturing. It is suggested that courses dealing with the manufacture of industrial dairy products may sometimes be combined, reducing the total credits, and thus permitting greater election in business administration or other fields.

SUBCOMMITTEE V—*Graduate Studies. Preparation for Master of Science and Doctor of Philosophy Degrees.*

A Bachelor's degree from a Land-Grant College or its equivalent with an undergraduate major in the field of specialization for graduate work, together with a grade average of 80 or B, is necessary for admission to a graduate college, provided also that the basic sciences and other requirements of the graduate college are met. Nontechnical curricula in agriculture do not always meet these requirements. In addition, specialization in the field of dairy production or dairy manufacturing may necessitate taking some undergraduate courses to provide the necessary background for graduate work.

MASTER OF SCIENCE DEGREE:

Where the Master's degree is to be considered as terminal, a balance of training between basic sciences and specialized courses in Dairy Husbandry and allied supporting work should be arranged. Caution is suggested to insure the development of a program that is representative of graduate level work, particularly where no thesis is required, to avoid awarding the Master's degree for merely a fifth year of undergraduate work.

The proposals set up for the technical curricula in both Dairy Production and Dairy Maufacturing are the minimum requirements for the preparatory work toward the Master's degree. For the thesis requirements, the time distribution is as follows:

1. Major: one-half the total credit requirement.
2. Thesis: one-fourth the total credit requirement, or the equivalent in time.
3. Minor: one-fourth the total credit requirement to be completed in a field related to the major area.

If no minor is required, then advanced course work supporting the major field should be substituted.

Language—a reading knowledge of one foreign language is desirable for the prospective candidate for the Ph.D degree; otherwise no requirement beyond the proper use of English.

Residence—two semester minimum.

Examination—a final comprehensive examination (either oral or written, or both) covering course work, seminar, outside readings, and research should be given after all residence and other requirements are completed.

DOCTOR OF PHILOSOPHY DEGREE:

Preparation—The candidate's committee should evaluate all previous training and accomplishments as to breadth, as well as depth, with a view toward strengthening weaknesses and building a good foundation.

Language—successful reading of two foreign languages, especially those that have literature in the major field.

Residence—two academic years beyond the Master's degree.

Course requirements—work leading to the Ph.D. degree should be designed to give the candidate a thoroughly comprehensive knowledge of the field of Dairy Husbandry and the underlying basic sciences, to train him in methods of research, and, at the same time, give emphasis to the development of an interest in teaching and good teaching techniques. With these objectives, the candidate for the Ph.D. degree should complete a satisfactory course of study, under the direction of a special committee, in one major and two minor fields. The relative amount of time spent on each field of study may be determined by the committee.

Thesis—Each candidate should present a thesis, usually based on original research in the major field, which is prepared under the supervision of the major professor or other member of the graduate faculty.

Examinations—Each candidate must pass a qualifying or preliminary examination, either oral or written, given by a special committee, usually at the completion of the first year of graduate work. Its purpose is to determine the qualifications of the candidate to continue work toward the doctorate, and, if successfully passed, to aid in planning future work. Upon completion of the graduate work, each candidate should pass a final examination conducted by his special committee covering major and minor fields and related subjects, as well as the thesis.

COMMITTEE PERSONNEL

Curriculum Committee—H. P. Davis, *chairman*
Production—I. W. Rupel, N. N. Allen, W. J. Tyler, and I. R. Jones
Manufacturing—E. L. Jack, W. M. Roberts, D. J. Hankinson, and L. K. Crowe

Subcommittee I. Basic Sciences—E. L. Jack, *chairman*
Production—G. H. Wise, W. E. Petersen, and Jay Lush
Manufacturing—B. L. Herrington, F. E. Nelson, and A. W. Farrall

Subcommittee II. Dairy Production—N. N. Allen, *chairman*
G. W. Trimberger, J. W. Linn, C. F. Huffman, P. M. Reeves, K. S. Morrow, and N. S. Lundquist

Subcommittee III. Dairy Manufacturing—W. M. Roberts, *chairman*
P. H. Tracy, L. C. Thomsen, Robert Jenness, W. J. Caulfield, P. R. Elliker, H. F. Judkins, and C. H. Wilster

Subcommittee IV. General Education—W. J. Tyler, *chairman*
Production—John Almquist, F. Irving Elliott, and Ralph Reece
Manufacturing—H. C. Olson, Mark Keeney Jr., and T. D. Harmon

Subcommittee V. Graduate Studies—I. W. Rupel, *chairman*
Production—N. N. Allen, Ralph Erb, and K. L. Turk
Manufacturing—Ira Gould, D. J. Hankinson, and E. L. Jack

PEOPLE and EVENTS
in the Dairy Science World

Pioneers in the Dairy Industry

We owe much to the men who first made extensive application of scientific principles to dairy plant operations. At the turn of the century, milk pasteurization was just coming into its own. The idea of centrifugal separation of cream was still new, and the Babcock test had just been perfected. Many problems needed to be solved. Among the scientists who accepted the challenge offered by the dairy industry at that time was LOOMIS BURRELL, a graduate of Yale (Ph.B., 1894) with a major in chemistry and physics. He taught analytical chemistry at Yale for one year before joining the D. H. Burrell Co.

Loomis Burrell

Loomis Burrell was born in Little Falls, Herkimer County, New York, July 31, 1872. His father was the founder of the D. H. Burrell Co. Young Burrell early in life developed an interest in science and even though a successful business man for many years he has always used a scientific approach to all problems. He would never accept half truth as an answer; he wanted facts. A source of great inspiration to Mr. Burrell was the young scientist he married in 1912—Lois Watson Wing, daughter of the late Professor H. H. Wing of Cornell Univ. At the time she met Loomis Burrell, Miss Wing was an instructor in Bacteriology at Cornell. These two young people working together were the first to develop chlorine sterilizers for use in sanitizing dairy equipment and utensils. This led in 1913 to the publication by the New York Agricultural Experiment Station of Circular 18, which gave detailed instructions on the use of hypochlorite solution for sterilizing dairy equipment.

Mr. Burrell started his climb to the top of his company by doing the simple but necessary tasks of a subordinate. His first job was to develop a cream separator, after which he was assigned the task of perfecting a milking machine. He was quiet and reserved and always added dignity to any occasion. In 1919 he became vice-president of the company and general manager of the Little Falls plant. In 1928 when D. H. Burrell and Co., Inc., joined with other firms to form the Cherry-Burrell Corp., Loomis Burrell became its first chairman of the Board, a position he still holds.

Many honors have been bestowed upon Mr. Burrell. He was a director in the Dairy and Ice Cream Manufacturers and Supplies Assoc. In 1932 he was appointed Consultant in Milk Sanitation in the U. S. Public Health Service, in which position he assisted in drafting the U. S. Public Health Service Milk Ordinance and Code. In 1937 he was appointed by Cordell Hull, then Secretary of State, as a delegate to the 11th Intern. Dairy Congress, which was held in Berlin. In 1941 he was made a member of the General Board for Dairy Research of the Dairy and Ice Cream Machinery and Supplies Association.

Throughout the years Mr. Burrell has maintained an active interest in scientific subjects, particularly as they applied to the materials used in manufacturing dairy equipment and their effect on milk flavor. He has also studied high-temperature short-time pasteurization and the cause and prevention of corrosion.

His keen mind has led Mr. Burrell to develop many worthwhile interests. His hobby is photography. He is chairman of the Board of Directors of Herkimer County Trust Co., vice-president of the Mohawk Valley Paper Co., the Burrows Paper Corp., and Reed Tissues, of Little Falls, New York. He is vice-president of the Board of the Auburn Theological Seminary and chairman of its finance committee. He has been president of the Board of Trustees of the Little Falls Public Library since 1911.

Mr. Burrell is a member of several business clubs and professional societies. In 1949 he was elected a member of the Scientific Research Society of America. In 1952 he received a bronze plaque and citation from Cornell Univ. Dairy Science Assoc. for outstanding work in connection with the dairy industry of New York state.

Although Mr. Burrell is 81 years old, he is too busy to retire completely. When in town, he is at his office every day. He spends a portion of his summers at "Brookbend," a summer home located north of Little Falls, and during the colder part of winter he will be found at Winter Park, Florida. The Loomis Burrells have three married daughters.

Loomis Burrell has ably demonstrated how well a professionally trained man can succeed in industry. He has further demonstrated the great possibilities that exist for a man of keen intellect and technical training to serve not only

industry but society in general. Mr. Burrell, our Society salutes you for your scientific and business successes and for the fine example that you have set for the young men of science through your splendid record as a pioneer in the dairy industry.

Penn State Changes Name

The Pennsylvania State College is now The Pennsylvania State University. Final approval was received through formal action of the Courts on November 13. This change in name is the third in the history of this institution, which was chartered as the Farmers' High School of Pennsylvania in 1855. In 1862 the name was changed to The Agricultural College of Pennsylvania and subsequently in 1874 the name, The Pennsylvania State College, was adopted.

In 1874 there were 144 students enrolled at Penn State with 11 faculty members. Today, 1953, there are 11,529 students on the campus with a full time resident faculty of 1,270. It is contemplated that the various schools within the institution will be changed to colleges. The University, however, will continue to be known as Penn State.

Roberts Heads Special Committee

W. M. ROBERTS, Head of Dairy Manufacturing in the Department of Animal Industry, North Carolina State College, has been appointed to the Public Health Service Milk and Food Sanitation Advisory Board as the representative of the A.D.S.A. Dr. Roberts is the chairman of the Assoc. committee which acts in an advisory capacity on regulatory matters. A. C. DAHLBERG and J. T. MILES are his associates on this important standing committee, whose work is to cooperate in every way possible with various regulatory agencies in the formulation of policies and programs affecting the dairy industry.

Soilax Appoints J. L. Wilson

JOHN L. WILSON has been elected to the Board of Directors of Economics Laboratory. This announcement came from M. J. OSBORN, Board Chairman. Dr. Wilson has been with Economics Laboratory since 1931 as director of research and development. He received his doctor's degree from the Univ. of Minnesota and is a member of a number of scientific societies. He has been active in economic and research aspects of chemistry, bacteriology, and engineering.

Reducing Diets with Milk

In order to prove to himself as well as others that it can be done, C. B. A. (BILL) BRYANT of Johnson and Johnson Co., Chicago, is among the latest to join the "Drink Milk and Reduce Club of America." Starting at 196 lb., Bryant lowered his weight 36 lb. in 60 days by careful control of his calorie intake, which included 1 qt. of whole milk and 2 oz. butter per day. Bill, a popular speaker at dairy short courses and dairy technology society and trade association meetings the country over, chose milk and butter for his reducing diet because of their high vitamin content and because he has always enjoyed dairy products. His diet was not monotonous, as it also included fruits, vegetables, lean meat, fish, and fowl in limited daily amounts.

He states that since he is down to the weight recommended by his doctor, he plans to continue eating in limited amounts but will add cheese and ice cream to his list of foods. When asked how he feels on his new diet, Bill replied, "I have never felt better in my life, never had greater energy, and feel as though I will easily live to be 100 years old."

Penn State Has Ag. Hill Party

For several years the School of Agriculture has had an Annual Ag. Hill party, which brings together the faculty, students, and employees for a supper and program. This year 1,500 people gathered in the recreation hall for the event. Aside from the turkey supper, the feature of the program is the annual presentation of scholarships to outstanding students. The yearly total for agricultural scholarships exceeds $6,000. Funds are provided by industry, trade associations, breed associations, and individuals. The dairy field is well represented, and the program is expanding rapidly with two dairy technology societies planning additional scholarships for next year. The majority of the grants are for $200 a year and are available primarily to sophomores and juniors.

The evening affair is planned and put on by the agricultural student clubs with advisory assistance from a faculty committee. Entertainment features include bingo and square dancing. The event is highly successful and definitely a permanent feature of student-faculty relations at Penn State.

W. H. Price Receives First Michigan State Dairy Manufactures Award

W. H. PRICE, director of milk procurement for the Ira Wilson and Sons Dairy of Detroit, was recently selected as the recipient of the first annual Michigan State College Dairy Manufactures Award. EARL WEAVER, Head of the Dairy Department, made the announcement of Dr. Price's selection on the occasion of the 14th annual Michigan Dairy Manufacturers Conference. Some 300 people, representing the leading dairy manufacturing interests of the state, were present to hear the citation read by P. S. LUCAS of the Dairy Department.

Since 1901, Dr. Price has been the leader in

the promotion of milk inspection, having pioneered this program with the Detroit Board of Health. In 1917 he joined the U. S. Public Health Service, where he supervised the procurement and processing of milk for our armed services during World War I. In 1920, Dr. Price returned to Detroit and joined the Detroit Creamery. Since 1932 he has been associated with the Ira Wilson and Sons Dairy.

The award was presented on the basis of Dr. Price's unselfish and steadfast efforts during the past 50 years to promote and improve milk supply for the people of Michigan. His efforts in this behalf have been instrumental in earning for the dairy industry an unprecedented and unparalleled position of consumer confidence in the wholesomeness of dairy products. Dr. Price is presently active as the director of the Michigan Milk Dealers Association.

Film Available on First Chicago Show

Students and teachers in dairy production will be interested in a 12-minute sound film of the first Intern. Dairy Show, held in Chicago October 10 to 17. The film, which will be sent free on request, depicts highlights in the judging of the six breeds of cattle that were featured by record entries at the initial show. It also shows scenes from the action-packed championship rodeo staged in conjunction with the dairy show.

Requests for film should be addressed to Intern. Dairy Show, Union Stock Yards, Chicago 9.

Dairy Waste Disposal Project at Penn State

For the past year, a dairy waste disposal project has been under way at Penn State. This is a cooperative project between the U.S.D.A. and the Departments of Engineering Research and Dairy Husbandry. The purpose of the project is to determine the most economical engineering design of disposal equipment for commercial dairies. A 20,000-gal. wooden tank has been constructed adjacent to the College Creamery with arrangements provided so that various types of dairy wastes can be pumped to the treatment tank. Specific studies are being made on air diffusion, rates of oxidation, and vitamin B_{12} production. Two commercial dairy plants are cooperating in this study. The biological effects of wastes, which are discharged from these plants into streams, are being investigated in order to determine necessary treatment.

The problem is of particular interest in Pennsylvania because of a recently instituted stream pollution program and law which makes dairy waste treatment mandatory.

Meetings at Ohio State

One hundred fifty people attended the fifth annual Dairy Technology Homecoming Celebration on October 31. The main event was the presentation of an award of merit to FRED M. CAMPBELL, Salem, Ohio, for his outstanding contributions to the dairy industry.

Meetings to familiarize the butter industry with the grading and inspection techniques of the Federal Food and Drug Administration were held in December. The meetings planned cooperatively by the Ohio Department of Agriculture, the Federal Food and Drug Administration, the butter industry, and the University, were held on the campus. The Ohio Department of Agriculture has now assigned one inspector to handle all butter quality activities of the Department.

Ohio State Wins Collegiate Students' Contest in Judging Dairy Products

Ohio State Univ. was the top winner on all counts in the Collegiate Students' International Contest in Judging Dairy Products held October 26, in Boston. The three-man team, coached by W. L. SLATTER, chalked up the Buckeyes' eleventh win and took the three top places in the over-all All Products Division, in addition to winning the coveted Milk, Butter, and Ice Cream cups. There were participants from 22 other U. S. and Canadian Land-grant colleges. Second winner was the Univ. of Connecticut, and Iowa State College was third.

Ohio State's win this year means that it again receives a $1,380 fellowship, which will go to a faculty-selected team member. The trade association of dairy equippers and suppliers also presented a $1,380 grant to second-place Connecticut and a $1,180 fellowship to Iowa State.

Contest sponsors believe this to be the first time in the contest's history that the three top medal winners have been from the same school. JACK H. FOWLER, 21-year-old senior from Caldwell, Ohio, became the world's top dairy products taster in winning the All Products gold medal for highest proficiency throughout the contest. Silver medal winner was RALPH L. PAUL of Canton, and bronze All Products medalist was ROBERT C. MILKIE of Bellevue, Ohio.

Winning teams also received silver cups for team proficiency and gold, silver, and bronze medals for individual scoring. Since a team winning one of the cups three times gets to keep it, Ohio State now has to win the coveted All Products Bowl only one more time to retain possession.

Ohio State Univ. also won three other silver cups in the separate product divisions Milk, Butter, and Ice Cream. Cornell Univ. won the Cheese Cup, with Ohio placing third. All but the Ice Cream Cup, which is given by International Assoc. of Ice Cream Manufacturers, are awarded by Dairy Industries Supply Assoc.

The Buckeye contestants also won the following: Milkie, the bronze All Products medalist, took home the gold Butter medal; Paul, silver

All Products medalist, won the gold Milk medal. Dairy Products Champion Fowler received the silver Milk medal and the silver Ice Cream medal.

Other High Ranking Teams

Colleges which placed in the second and third team-standing spots in individual product divisions were:

Milk—Iowa State, second; North Carolina State College, third.

Butter—Univ. of Maryland, second; Iowa State College, third.

Ice Cream—Univ. of Connecticut, second; Univ. of Maryland, third.

Cheese—Univ. of Connecticut, second; Ohio State Univ., third.

C. J. BABCOCK, in charge of the Dairy Branch Standards Section of the U.S.D.A., was contest superintendent in his 26th year of contest participation. G. M. TROUT, Michigan State College, headed the A.D.S.A. contest committee, and FRED FLEMING, the DeLaval Separator Co., had charge of the corresponding committee of D.I.S.A.

Product judges were: R. WHITAKER, National Dairy Research Lab., milk; N. E. FABRICIUS, Ladysmith (Wis.) Milk Producers Cooperative Assoc., butter; H. L. WILSON, Kraft Foods Co., cheese; and J. HOFFMAN ERB, The Borden Co., ice cream. Mr. Wilson was honored at the Awards Dinner for his 25-year participation as Cheese Judge.

The contest arrangement subcommittee was headed by ROBERT ROSENBAUM, David Michael & Co., Philadelphia. NORMAN MYRICK, Editor, American Milk Review, was in charge of the Awards Dinner and was its Master of Ceremonies.

Mississippi State Happenings

A. M. SORENSON joined the Dairy Production staff at Mississippi State College September 1, 1953. Dr. Sorenson received his undergraduate training at Texas A & M and completed the work for a Ph.D. degree at Cornell Univ. in June 1953.

J. COLLINS, Instructor in Dairying, resigned June 30, 1953, to accept a position as manager of the Mississippi Artificial Breeders Cooperative at State College.

J. H. KRAFT, Chairman of the Board of Kraft Foods, was the principal speaker at a banquet on October 23 that brought to a close a 2-day Dairy Farm Youth Short Course for Kraft Junior dairymen from the states of Kentucky, Tennessee, North Carolina and Mississippi. W. E. MITCHELL, Div. Production Manager of Kraft Foods Co., Atlanta, presented GLEN PARKS from Tennessee and THOMAS HASSEL from Mississippi each with a $300 scholarship for being the outstanding Kraft junior dairymen who had completed 4 years of dairy club work in the southeastern division.

Revised Textbook Off the Press

Publication of the fourth edition of *Dairy Cattle Feeding and Management*, by H. O. HENDERSON, Professor of Dairy Husbandry at West Virginia, and PAUL M. REAVES, Professor of Dairy Husbandry at Virginia Polytechnic Institute, has been announced by John Wiley and Sons, Inc. The book is based upon the original work by Larson and Putney. The revised edition includes much new material covering recent advances in the field of dairy cattle feeding and management.

Events at Michigan State

W. W. SNYDER has returned after 18 months of teaching at the Agricultural College in Medellin, Colombia. J. D. JOHNSON, on leave from his county agent's post, follows Prof. Snyder on a 2-year assignment.

EARL WEAVER, head of the Dairy Department, became the new president of the Dairy Shrine Club during the Intern. Dairy Congr. at Waterloo, Iowa.

The 14th Annual Michigan Dairy Manufacturers Conference was held at M.S.C. on Nov. 4 and 5. The program featured speakers from several universities and industrial organizations. An innovation at this year's meetings was a Products Clinic, at which plant men could discuss their problems.

The third annual Dairy Cattle Breeders' Conference was held at M.S.C. on Nov. 9 and 10. This conference has been popular with Michigan breeders. C. J. RENNE of the Ontario Agricultural College was a featured speaker.

10th International Congress of Agricultural and Food Industries

At the invitation of the Spanish government, the 10th Intern. Congress of Agricultural and Food Industries will be held in Madrid May 30 to June 6, 1954. Detailed programs can be obtained from the Secretary of the Congress, SR. D. RAMÓN BENEYTO SANCHIS, Zurbano, 3, Madrid.

At the specialized sessions papers will be given on problems pertaining to the sugar, fermentation, distillation, cereal, dairy, conserves, condiment, cattle nutrition, animal and vegetable fat, wood, cellulose, tobacco, essential oil, leather, and cold storage industries.

During and after the Congress visits will be made to places of scientific and artistic interests.

West Virginia to Hold Meeting

The 13th annual W.V.U. Dairy Short Course will be held at Jackson's Mill, Weston, W. Va., January 5-8, 1954. Outstanding authorities in both the production and manfacturing fields will bring the dairymen of the state up to date on new developments in the industry.

Ernstrom Joins Wisconsin Staff

CARL A. ERNSTROM has been appointed Extension Specialist in Dairy and Food Industries at the Univ. of Wisconsin. Mr. Ernstrom received his M.S. degree at Utah State College and, in addition to his duties as extension specialist, is completing his research for a Ph.D. degree at the Univ. of Wisconsin.

New Laws and Regulations in Dairy and Food Field in Wisconsin

A new law in Wisconsin now recognizes the standardization of milk by permitting the removal of cream or the addition of cream or skimmilk. Heretofore, uniformity of milk fat and fluid milk for consumer use was achieved only by blending high fat and low fat milk from different producers. The minimum standards of 3% butterfat and 8.25% milk solids-not-fat remain in the definition.

The following are new standards for ice cream and frozen desserts: Custard ice cream now must have a minimum egg yolk solids content of 1.4% of the weight of the finished product. This has been changed from the old law that specified it as 1 2/3 oz. per gallon. The milk fat content of ice milk is required to be from 3% up to that prescribed for ice cream. The nonfat milk solids content may not be less than 12%. The definitions for sherbet indicate that this product must contain not less than 1% milk fat, not less than 2% total milk solids, and not less than 0.35% acidity to be calculated as lactic acid. Water ices are to be of the same acidity as sherbets, and must weigh not less than 6 lb. per gallon.

Wisconsin now has a compulsory tester's licensing law. This requires the annual licensing of milk and cream testers. Licensed cheese makers and licensed butter makers are exempt, but the bill provides that no dairy plant may receive milk or cream unless a licensed tester is responsible for the samples and is regularly assigned the duty of making the tests.

There is also a compulsory butter grading law, under which any butter offered for sale must have a grade mark on the label of the package. The grades are the same as the United States standards except that all grades below 90 or Grade B are classified as undergrade butter.

Completed Theses

M.S. Degree:

DERO S. RAMSEY—The feeding of cottonseed meal and corn versus whole cottonseed in a balanced dairy ration. Miss. State College.

JAMES H. BENDER—The relation between certain skimmilk constituents and the yield of cottage cheese. Univ. of Illinois.

Ph.D. Degree:

JOHN H. NELSON—Effects of design of apparatus upon the ultrasonic process for accelerating the ripening of cheese. Univ. of Wisconsin.

MARIE BURGER—Homogenization and deaeration of milk by ultrasonic sound waves. Univ. of Wisconsin.

LEO J. HANSEN—A critical comparison between tinned steel milk cans and stainless steel milk cans. Univ. of Wisconsin.

A Change in Philosophy Needed for A.D.S.A.

A Guest Editorial

The original constitution of the American Dairy Science Association declared its object to be "to advance the general welfare of the dairy industry, especially for improvement of dairy instruction, by the stimulation of scientific research in all phases of the subject and by the improvement of methods in conducting extension work." This statement clearly expressed the professional ideals and defined the motives of its founders. It indicated that industry leadership was a definite part of their objectives, along with teaching and research. They believed that promotion of the growth and development of the dairy industry was a part of their obligation to the national welfare.

P. M. Brant

The Association adopted a new constitution on June 24, 1943. On that date it limited its responsibility in the field of industry leadership "to cooperate in educational development in advancing the general welfare of the industry." In the desire to emphasize research, scholarship and academic accomplishment, responsibility for participation in aggressive industry leadership was definitely subordinated in the constitution. In addition, activities in that direction were discouraged as being "political" in nature when important problems were proposed to the Board of Directors for consideration.

This aloofness from what some have described as "promotional" activities may have been merely a reflection of a similar change which occurred in the spirit of many of the Land-Grant Colleges and Universities. It is much easier to suggest that "we need more research" or to encourage the acceptance of federal aid than to participate in a rugged attempt to solve industry or farm problems by engaging in what may turn out to be unpleasant controversies.

There may be no traceable connection between the American Dairy Science Association's constitution and the dairy industry's present plight.

The effect of the attitude which inspired and approved the changes mentioned, however, is highly significant. Still more important is the effect of these changes on the spirit of dairy specialists. Regardless of the cause, it is apparent that the abdication by dairy scientists from responsibility in the field of public leadership has been an invitation to others to take over. Others, notably the economists, have taken over.

Dairy scientists should not only maintain technical leadership in their field but recognize the practical needs of the industry. The Association must encourage a renewal of interest in the welfare of the dairy farm family. Its membership must again think of dairying as a type of farming that helps to maintain the American standards of living on the farm as well as in town. This doctrine needs to be particularly impressed upon the younger generation of workers whose horizon too frequently is limited to the laboratory. We need to return to the philosophy which inspired us when the dairy industry was regarded as the keystone of agriculture and good living. This can be accomplished without turning back the pages of history and without loss of professional dignity.

P. M. BRANT, Head
Dept. of Dairy Husbandry
Oregon State College

LETTERS TO THE EDITOR

Secretary Benson Asks for Suggestions

The Honorable Ezra Taft Benson, Secretary of Agriculture, is asking us to suggest projects in research, extension, and education to strengthen American agriculture. This is an opportunity, perhaps the first which this Association has had, to use directly the broad knowledge, experience, and judgment of our members for the nation's welfare. We are urging you to meet this request in this way:

What project in research, extension, or education in the broad field of dairying will do most in your opinion to strengthen American agriculture?

1. State your project as a title which will indicate the primary objectives. Put your title in the form of a question to be answered if you choose.

2. Write your title on an 8½ x 11 inch sheet of paper. Place your name and address on this page so that the project can be discussed with you if necesary. Please leave a 2-inch margin on the left to permit binding.

3. Meet this challenge with thoughtful, prompt action. Your project will be in the hands of Secretary Benson by January 25th if it reaches me at the University of Wisconsin, Babcock Hall, Madison 6, by January 15th.

WALTER V. PRICE, *President*
American Dairy Science Association

Committee to be Appointed to Study Order of Seniority on Papers

A systematic order of naming authors of scientific papers could add materially to the readers' information. Professor R. McL. Whitney in his letter to the Editor in the November issue of the Journal advanced some sound arguments for a standardized and publicized arrangement to eliminate the confusion of unknown and variable procedures.

It is true that one cannot now be certain of the identity of the senior author or the junior author, or the extent to which other authors listed have contributed to the work and preparation of the paper. Order of naming sometimes depends on the custom or policy of the institution in which the work was done. Pride or modesty may dictate the order of listing names rather than the nature and extent of each individual's contribution. The complications multiply when a project director finds it necessary to write a paper based on the unpublished thesis of a former graduate student who became involved in the duties of a permanent position too soon to prepare his thesis for final publication.

Professor Whitney recommended that the President of the American Dairy Science Association consider the appointment of a committee to formulate a policy on the order of naming authors of papers published in the *Journal of Dairy Science*. The suggestion is sensible and reasonable. A committee is being appointed to assemble information on practices and opinions and to present its findings and recommendations to our Journal Management Committee for action.

Thank you for the suggestion, Professor Whitney.

WALTER V. PRICE, *President*
American Dairy Science Association

OUR INDUSTRY TODAY

Brief Reviews of Current Topics

HOW EFFICIENT CAN THE DAIRY COW BECOME?[1]

Efficiency Results from Improvements in All Phases of Production

C. R. HOGLUND

Michigan State College and Bureau of Agricultural Economics

The dairy cow has long been proclaimed as the most efficient of the farm animals. Research results show that a dairy cow has no peer in converting 100 lb. of feed nutrients into essential protein for human consumption. However, individual cows vary greatly as to the efficiency with which they produce milk, from both a physical and economic point of view. Recent studies conducted at Michigan State College show that the quantity of concentrates used in producing 100 lb. of milk varied from only 20 to more than 50 lb. The cost of the feed needed to produce this 100 lb. of milk ranged from $1.18 to $2.35.

Cow's Efficiency Dependent upon Management

Differences in efficiency of individual cows must be credited to factors that are inherent in the cow as well as those that are man-made, or at least man-controlled. Individual dairymen themselves are especially important in determining how efficient their dairy cows can become. Management decisions influence the genetic make-up of the cows as determined by breeding and selection practices. The quality and kind of feeds produced depends on the dairyman's judgment and timing in applying recommended practices. Efficient use of feed is dependent not only on the inherent productivity of the cows and the quality of roughage fed but also on the combinations of feed, the cows' environment, and the control of disease and parasites.

Cow's Producing Capacity Important

The inherent productivity of a cow is by far the most important single factor that influences efficiency in producing milk. The cow with average producing capacity (for Michigan 245 lb. b.f. or 7,000 lb. 3.5-test milk) will always be an inefficient producer regardless of how well she is fed and cared for. Such a cow requires about 0.5 lb. TDN to produce 1 lb. of milk. At current prices, medium-quality roughage, and with a favorable environment, the best she can do is to earn for her owner 46 cents an hour for his labor and management (Figure 1).

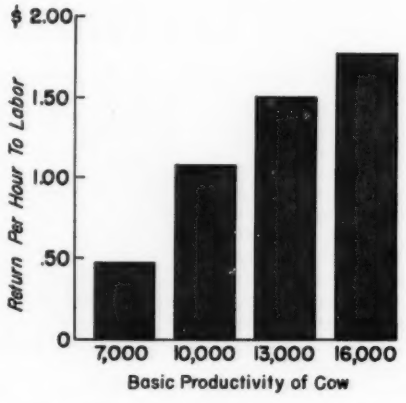

FIG. 1. Average hourly returns to labor and management for cows having basic productivity of 7,000 to 16,000 lb. 3.5% milk. Medium quality roughage fed. Prices used: Grain $2.20 cwt.; protein supplement $4.70 cwt.; hay $20 ton; silage $8 ton; and pasture, poor-$20, medium-$22.50, and excellent $25 acre. Milk valued at $4.00 cwt.

A dairyman who is successful in attaining a 10,000 lb. milk production average for his herd (350 lb. b.f.) can produce a pound of milk with only 0.4 lb. TDN. This is a saving of 20% in feed over that produced by the average cow mentioned above. This higher producing cow will return her owner about $1.15 an hour, or two and a half times as much as the lower producing animal. Raising the producing ability of a cow to 13,000 lb. milk will reduce the feed nutrient requirements by an additional 10% and will add 35 cents an hour to labor returns.

A dairyman who has attained a 16,000 lb., or greater, production average for his herd is indeed a successful operator. At least, his cows will be efficient if given the proper environment and management. Such high-producing cows will net their owner four or five times as high a return for his labor as will average cows. The

[1] Journal Article 1575 from the Michigan Agricultural Experiment Station.

feed cost of producing 100 lb. of milk, at current prices and with medium-quality roughage, would be about $1.26, as compared to a feed cost of $2.07 for the average animal.

Quality of Roughage Related to Efficient Milk Production

Improving the quality of roughage is one of the most realistic opportunities for reducing milk production costs. A recent Michigan study shows that the cost of feed used in producing 100 lb. of milk could be reduced by as much as 10 to 25% if dairymen would improve the quality of their roughage and if they would substitute roughage for part of the grain and protein fed. Dairy farmers who produced and fed excellent quality roughage fed 1,300 lb. less grain and 330 lb. less protein supplement in attaining about the same production of milk (11,700 lb.) as did dairymen who produced and fed poor roughage.

Much of the potential benefit from higher producing cows can be lost when roughage of poor quality is fed. A cow with the inherent capacity to produce 16,000 lb. of milk, when fed poor roughage, will have almost as high feed costs in producing 100 lb. of milk as a cow with 10,000 lb. production capacity fed excellent roughage (Figure 2). Improving the

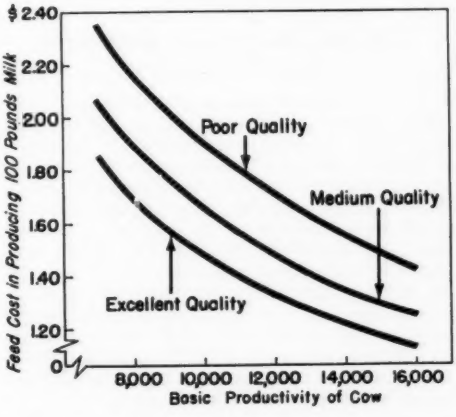

FIG. 2. Estimated average feed costs in producing 100 lb. of milk when roughage quality is poor, medium, and excellent, and basic productivity is 7,000 to 16,000 lb. per cow.

quality of roughage from poor to medium on dairy farms where 10,000 lb. producing cows are kept will add about $24 to labor and management returns per cow. Improving the quality of roughage from medium to excellent would add an additional $18 per cow to these returns. The extra returns resulting from improved quality of roughage are even greater for the higher producing cows.

The question often arises as to whether the extra costs involved in producing excellent roughage are justified. It costs about $8 more to produce an acre of excellent quality than an acre of poor quality roughage, based on a study of feed production and feeding practices carried out on 34 Michigan dairy farms. Most of the excellent roughage was grass silage or barn-dried hay, and the poor roughage was loose or baled hay. A 33% greater yield of feed nutrients from an acre of the high quality roughage resulted in a 12% lower cost. Thus the higher quality roughage contributed to increased efficiency by *(a)* reducing grain and protein needs and *(b)* lowering per unit cost of roughage.

Feeding Schedules Must be Under Constant Change for Maximum Efficiency

Economic as well as technical efficiency needs to be considered in arriving at the most profitable combination of feeds. Economic efficiency, which is determined by both technical efficiency and relative prices for different feed inputs, involves the practical combination of feeds. If a dairyman was primarily interested in producing 100 lb. of milk with the least input of TDN, he would feed largely roughage but would sacrifice both production and returns above feed costs. On the other hand, pushing cows for maximum production can materially reduce these returns.

There is no one most profitable level of grain feeding for all times. This level is determined by such factors as *(a)* the production response of cows differing in inherent productivity, *(b)* the quality of roughage, and *(c)* the price relationships for feed and milk and grain and roughage. Dairy farmers are faced with the problem of making continual changes in their feeding program if maximum efficiency is to be attained. To make intelligent decisions in adjusting the feeding program to new conditions, it is necessary to know the production response of individual cows in the herd. It is then possible to apply current prices to feed inputs and milk output and determine the most profitable level of grain feeding.

As additional quantities of grain are fed to a cow that has free access to roughage, she eats somewhat less roughage but her intake of TDN increases and total output of milk is increased. While milk output increases with the increased TDN intake, each increment of feed produces less milk than the preceding one. The point of most economical efficiency is reached when the cost of the last input of feed (includes cost of additional grain minus the value of the roughage saved) just equals the value of the additional milk produced. The most profitable combination may vary considerably from time to time, depending on the feed-milk and grain-roughage price ratio.

Price Relationships Must Be Considered

The normal relationship between the price of grain and the price of hay is about 3:1 (a ton of grain costs 3 times as much as a ton of hay). With a farm price of $2.80 a cwt. ($56.00 per ton) for grain, $18.60 a ton for hay and $4.00 a cwt. for 3.5% milk, the most profitable amount of grain to feed, when good cows are fed medium quality hay, would be 2,750 lb. (Figure 3).

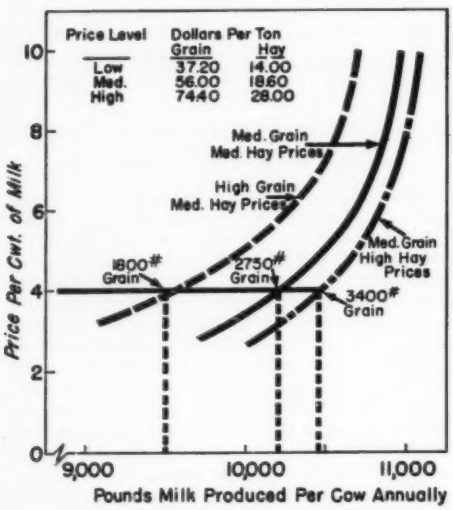

FIG. 3. Marginal cost in producing 100 lb. of milk, medium quality roughage and good cows (10,000 lb. producing capacity), three grain-hay price relationships.

At this level of grain feeding the last input of feed just pays for itself in the value of the added milk produced. In other words, the additional or marginal cost equals the marginal returns at this point.

When hay is high in price relative to grain (hay at $28.00 a ton and grain at $56.00 a ton), the most profitable rate of grain feeding would be at the 3,400 lb. level. This is the situation that existed in western Kentucky and other drought areas during the winter feeding period of 1952-53. If grain should become high relative to hay (grain at $74.40 a ton and hay at $18.60 a ton), it would pay to feed only about 1,800 lb. of grain to good cows (Figure 3). Milk production per cow for these three feeding situations is estimated to be 9,500 lb. for the low, 10,200 lb. for the medium, and 10,450 lb. for the heavy rates of grain feeding (Figure 3).

If farm price of milk were $5 rather than $4 per cwt., it would pay to feed 500 or 600 lb. more grain per cow under the three price situations outlined. A higher output of milk would then be expected. A reduction in the price of milk would suggest lower rates of grain feeding, resulting in a lower output of milk. Thus, price relationships become important in attaining maximum efficiency in the production of milk.

Disease May Be Cause of Reduced Efficiency

Disease is often an important factor in reducing the efficiency of a dairy cow. Dairy researchers have estimated that reproductive and infectious diseases, taken together, reduce total milk production by as much as 25% each year. Disease may thus have the same effect on efficiency as reducing the production capacity of a cow from 13,000 to 10,000 lb. of milk.

Dr. W. E. Peterson, dairy scientist at the University of Minnesota, has observed the effect of mastitis on identical twins receiving the same ration. He found that mastitis resulted in a 16% loss in milk production for a partial lactation period and almost 25% for the next lactation for one cow of a pair of identical twins. Diseases affecting reproduction may take an even greater toll in reducing milk output and income. Dairy researchers at Michigan State College have estimated that these milk production losses can be cut in half in the next few years if dairymen will adopt recommended prevention and control measures.

For Best Results Cows Must Have Good Environment

A cow's environment is controlled to a large extent by man. He cannot change the weather, but he can do much about buffering the effects of wind, moisture, and other climatic conditions. A dairyman can provide environmental conditions that will make the most efficient use of a cow's capabilities or he can provide conditions which are so adverse that the cow cannot economically utilize feed and other resources. Use of the best barn arrangements and improved equipment and work methods can add to the comfort and productivity of the dairy cow and at the same time reduce labor requirements. A dairyman can also lessen man-made disturbances that reduce a cow's efficiency.

All Factors Must be in Balance

The pay-off in dairy efficiency comes when a dairyman makes improvements in all phases of his production program. A dairyman who starts out with average cows and average efficiency can triple his labor income by improving the quality of his cows, by adopting the best production practices, and by adding enough cows to use up the increased feed produced (Figure 4). A change to a larger farm and more cows has a relatively small effect on labor income when average cows and average production methods are used.

Consideration Should be Given to Cow's Capacity to Digest Roughages

The need for improving the efficiency of the dairy cow is especially important at a time when high production costs are putting a squeeze on dairy profits. There is room for tremendous improvement in the physical efficiency of the dairy cow.

The dairy cow is especially built to handle roughages. She has the capacity to consume and utilize large quantities of roughage, yet dairy researchers and breeders as a group have failed to take advantage of this very important factor in breeding and selecting dairy cows for future production. Very few breeders have selected cows specifically for their efficiency in handling large quantities of roughage. Rather, they have selected cows that have achieved high records when fed large quantities of grain. Dr. C. F. Huffman, dairy nutritionist at Michigan State College, has pointed out that cows vary greatly in their ability to utilize roughage efficiently. A great deal of research needs to be carried out in this area if the dairy cow is to achieve even greater efficiency.

Further Research Needed

Another area of research that needs further exploration is that dealing with the breeding and selection of improved legumes and grasses. There is need for hay and pasture species that remain palatable for longer periods of the growing season and yet produce large quantities of highly nutritious forage per acre. A combination of improved roughage-consuming cows and better forages would add greatly to present efficiency.

An additional important problem is one dealing with the rate at which roughage is substituted for grain when various qualities of roughage are fed to cows differing in their inherent capacity to produce milk. New Zealand and the Netherlands have been cited as good examples of countries where maximum use is made of roughages. Is this situation attainable or economically feasible in our country? If not, how far can dairymen go in the direction of an all-roughage ration? These and similar questions can be answered adequately only through cooperative research by agronomists, dairy specialists, and production economists.

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* Abstract of paper presented at the annual meeting.

[a] Prepared by W. O. Nelson, Univ. of Illinois.

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JOURNAL
OF
DAIRY SCIENCE

VOLUME XXXVI
JANUARY — DECEMBER 1953

1953
THE AMERICAN DAIRY SCIENCE ASSOCIATION
THE OHIO STATE UNIVERSITY, COLUMBUS, OHIO

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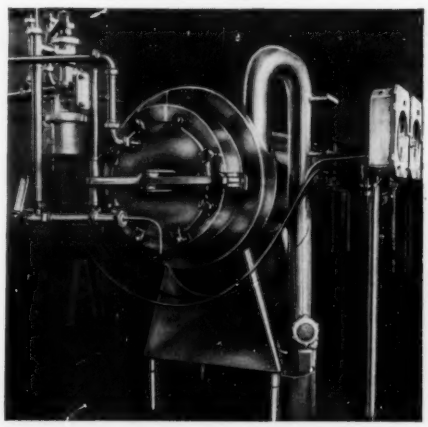

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